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UPPER CAMBRIAN GRAPTOLITES FROM VIRGINIA AND TENNESSEE

CHARLES E. DECKER AND IRWIN B. GOLD
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ABSTRACT—Study of Upper Cambrian graptolites at high magnifications reveals the presence of structures not commonly recognized: gonothecae (representing the female element) and nematothecae (originally housing the stinging cells). These new structures have great significance for classification of graptolites, and indicate that graptolites are related to the Coelenterata rather than to the Hemichordata.

The study is based on collections from two localities, one in Virginia and the other in Tennessee. Some of the earliest dendroid graptolites known to occur in abundance were secured from two zones 30 feet apart in the Upper Cambrian Nolichucky shale in Virginia. The lower zone is 75 feet and the upper zone is 45 feet below the top of the formation. In the lower zone there are 6 genera, 9 species, and 3 varieties, of which 6 species and one variety are new; in the upper zone there are 5 genera, 10 species, and 4 varieties, of which 5 species and 3 varieties are new. Of the total of 9 genera, 16 species, and 4 varieties found in the two zones, only 4 species and 2 varieties occur in both zones.

An excellent collection of Upper Cambrian graptolites was made by the senior author and assistants in the Tecoy quarry, Knox County, Tennessee. On each of several return visits to the quarry additional graptolite colonies were obtained. The fauna includes 28 species and 6 varieties, of which 22 species and 3 varieties are new.

The species and varieties are illustrated by photographs. Colonies are photographed ×1 or ×2 to show their size and shape, and parts of colonies are highly magnified to show thecae, bithecae, gonothecae, nematothecae, and, in some instances, polyps with nematothecae preserved by calcification. It is very difficult to get good photographic enlargements of parts of colonies where graptolite stipes and adjacent matrix have only slight contrast in color. Moistening specimens with bay rum gave best results, because adjacent substances had different rates of absorption and evaporation.

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PART II: UPPER CAMBRIAN GRAPTOLITES FROM TECOY QUARRY, 7.5 MILES WEST OF KNOXVILLE, TENNESSEE

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PART I: UPPER CAMBRIAN GRAPTOLITES NEAR GRATTON, SOUTHWESTERN VIRGINIA

ACKNOWLEDGMENTS

IN THE collecting and study of the Upper Cambrian graptolities of Virginia, the senior writer gratefully acknowledges the assistance of the following:

In the early stages of collecting Upper Cambrian graptolites of Virginia, Arthur Bevan, State Geologist of Virginia, assigned Byron Cooper, Associate Geologist of the Virginia Geological Survey, to assist the writer in collecting the graptolites, and arranged for the payment of our travelling expenses.

Byron Cooper took the senior writer to the Gratton, Virginia, graptolite area and helped collect graptolites from the main lower graptolite zone, which had been discovered by Robert O. Bloomer, a student assisting in the field study of the Burkes Garden geology in preparation for the publication of Bulletin 60 of the Virginia Geological Survey. While Byron Cooper and the writer were collecting graptolites from the main lower Gratton zone, William Randall Brown, Chemist for the Virginia Geological Survey, discovered another graptolite zone 30 feet higher in the section, and the higher zone yielded almost as many genera and species of graptolites as the lower one. Later, Don Kelso, a student assistant, helped collect more graptolites from the Gratton, Virginia area.

Much credit should be given the University of Oklahoma Research Committee with A. O. Weese as Chairman, for assistance in meeting part of the field expenses, for paying the University Photographic Service for photographic work, and for continuing to secure photographic supplies as the study of the graptolites has progressed.

When the senior writer was retired as Research Professor Emeritus, V. E. Monnett and Carl Branson planned a new five-year Decker Fellowship with a deeply interested alumnus giving $750.00 per year for a student to assist in the graptolite studies.

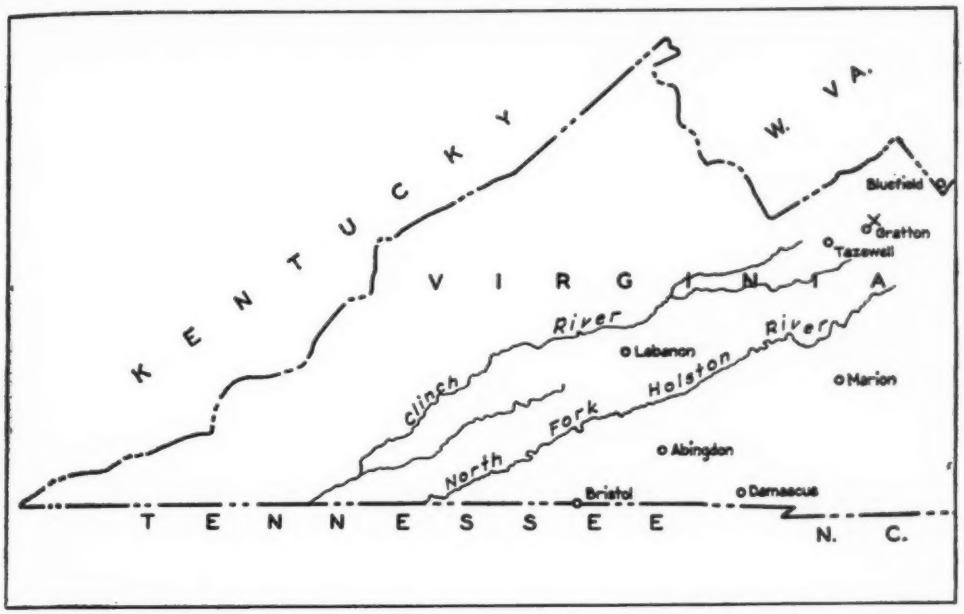
As the senior writer had found on these early graptolites, new structures which had not been commonly recognized, it has seemed desirable to get photographic enlargements instead of camera lucida drawings.

The difficult task of getting the photographic enlargement of the graptolites has been assigned the student assistants, and Roger Billings and Harry Smith served temporarily, but it is to Irwin B. Gold that most of the credit is due for getting good photographic enlargements. For his patient, persistent efforts in this work he is being credited as junior author.

INTRODUCTION

Byron Cooper, associate geologist on the Virginia Geological Survey, worked out the geology of the Burkes Garden quadrangle in preparation for publication of Bulletin 60 of the Virginia Geological Survey. While Cooper was working out the geology of the area, Robert O. Bloomer, a student assistant, discovered the main lower graptolite zone. Later, while Byron Cooper and the senior writer were collecting graptolites from the lower zone, William Randall Brown, chemist for the Virginia Geological Survey, discovered a second graptolite zone 30 feet higher in the formation.

Location.—The graptolites occur in the Burkes Garden quadrangle of Southwestern Virginia on the north side of State Highway 61, 1.5 miles east of Gratton, Virginia. On the west side of a fence, a private road leading north branches to the right several hundred feet from the highway and passes through the fence in a northeasterly direction along a tiny stream for about 400 feet to a low fall at the left of the road caused by a resistant limestone bed. About 40 feet east



TEXT-FIG. 1—Outline map of southwestern Virginia showing Gratton between Bluefield and Tazewell about 50 miles northeast of Bristol. The graptolites occur 1.5 miles east of Gratton. Scale: One inch = 22.5 miles.

of the road the 12-inch limestone dips 50° to the southeast and helps to form a short, steep slope along the north side of a low ridge. The coarsely crystalline limestone contains small fragments of trilobites and graptolites. Above this limestone, the graptolite zone is 15 to 18 inches thick in a bluish-gray indurated shale.

The second zone occurs 30 feet higher on the rough flat-topped, low ridge in thin, highly indurated, brown dolomitic shale through a zone of a foot or more.

PREVIOUS WORK

First to be reported is the work of Charles Butts (1940, p. 79–86) in his report on the Geology of the Appalachian Valley in Virginia. He described the Nolichucky shale giving 3 detailed measured sections and a list of 38 fossils from the formation.

Byron Cooper (1944, p. 4–6,22) credited 12 men with assisting him in preparing the report on the Geology of the Burkes Garden Quadrangle, and lists 10 who had done previous work on the geology of the area.

FOSSILS AND CORRELATION

Butts (1940, p. 85,86) has listed over 30 species of fossils, chiefly trilobites and brachiopods, from the Nolichucky shale and concluded that the Nolichucky is equivalent to the Eau Claire shale of Wisconsin, and states further that the Nolichucky corresponds to the lower half of the Upper Cambrian of Wisconsin and Missouri.

Byron Cooper (1944, p. 22,23) has listed 12 trilobites and brachiopods from the Nolichucky shale and indentified the following upper Cambrian graptolites from the Gratton outcrop.

Acanthograptus sp.
Callograptus antiquus Ruedemann
Dendrograptus sp. cf. *D. hallianus* (Prout)
Dendrograptus edwardsi major Ruedemann
Haplograptus sp. cf. *H. vermiformis* Ruedemann

Cooper concludes that the Nolichucky of the Burkes Garden gradrangle probably does not include the lowest beds of the type Nolichucky of Tennessee, but that the middle and upper parts appear to be fully repre-

sented, and shows that the chief trilobites of the Nolichucky shale occur in the Eau Claire member of the Dresbach formation of Wisconsin, indicating that the age of the Nolichucky is Early St. Croixan. Cooper states further that the Nolichucky is believed to be equivalent to the upper part of the Elbrook formation of the southeastern Appalachian belts, and to the upper part of the Conasauga formation of Alabama.

The Nolichucky shale is thus equivalent to the Eau Claire member of the Dresbach formation, which is separated by 6 younger members from the Lodi graptolite-bearing member of the Trempealeau formation of Wisconsin and Minnesota. We would, therefore, expect the graptolites of the Nolichucky shale to differ considerably from those of the much younger Lodi shale. The species *Dendrograptus* sp. cf. *D. hallianus* listed above by Cooper is here called *Dendrograptus hallianus moneymakeri* Ruedemann, described from the Tecoy quarry 7 miles west of Knoxville, Tennessee. The latter variety differs greatly from the original Lodi species in form, and has much smaller and more numerous thecae in 10 mm. Similarly, *Dendrograptus edwardsi* Ruedemann from the Lodi shale is represented by *Dendrograptus edwardsi* var. *grattonensis* Decker & Gold, n. var., with a long narrow colony which differs materially in form from *D. edwardsi* and *D. edwardsi* var. *major*. Another Lodi shale species, *Callograptus staufferi*, is represented in the Nolichucky shale by *Callograptus staufferi* var. *bloomeri* Decker & Gold, n. var., which differs from the original species in form, more closely set stipes, and shorter and more numerous thecae in 10 mm. than the original species. Also, the fauna of the lower zone has 6 new species, and thus differs greatly from that of the Lodi shale.

Four species in the two Virginia zones are like those in the Upper Cambrian of Mason, Texas. For this reason, it is thought that the Nolichucky correlates well with the Wilberns formation of Texas (see table 1).

James Lee Wilson (1952, p. 275) table, pl. 4) in his recent article on the Central Appalachians places the Nolichucky shale opposite the middle Dresbachian.

Recent studies by W. Charles Bell et al. (1952, p. 175) show that boundaries of rock facies and faunal formation zones in Upper Cambrian do not coincide, and that changes in members and formations will be needed. Inasmuch as results of those studies are still not available, the accepted boundaries and names of members and formations are used.

The following genera, species, and varieties are described from the Virginia lower zone (see pls. 1–3):

Dendrograptus edwardsi var. *grattonensis* Decker & Gold, n. var.
D. hallianus var. *moneymakeri* Ruedemann
D. kindlei Ruedemann
D. thomasi Ruedemann
Syrrhipidograptus burkesgardenensis Decker & Gold, n. sp.

EXPLANATION OF PLATE 47

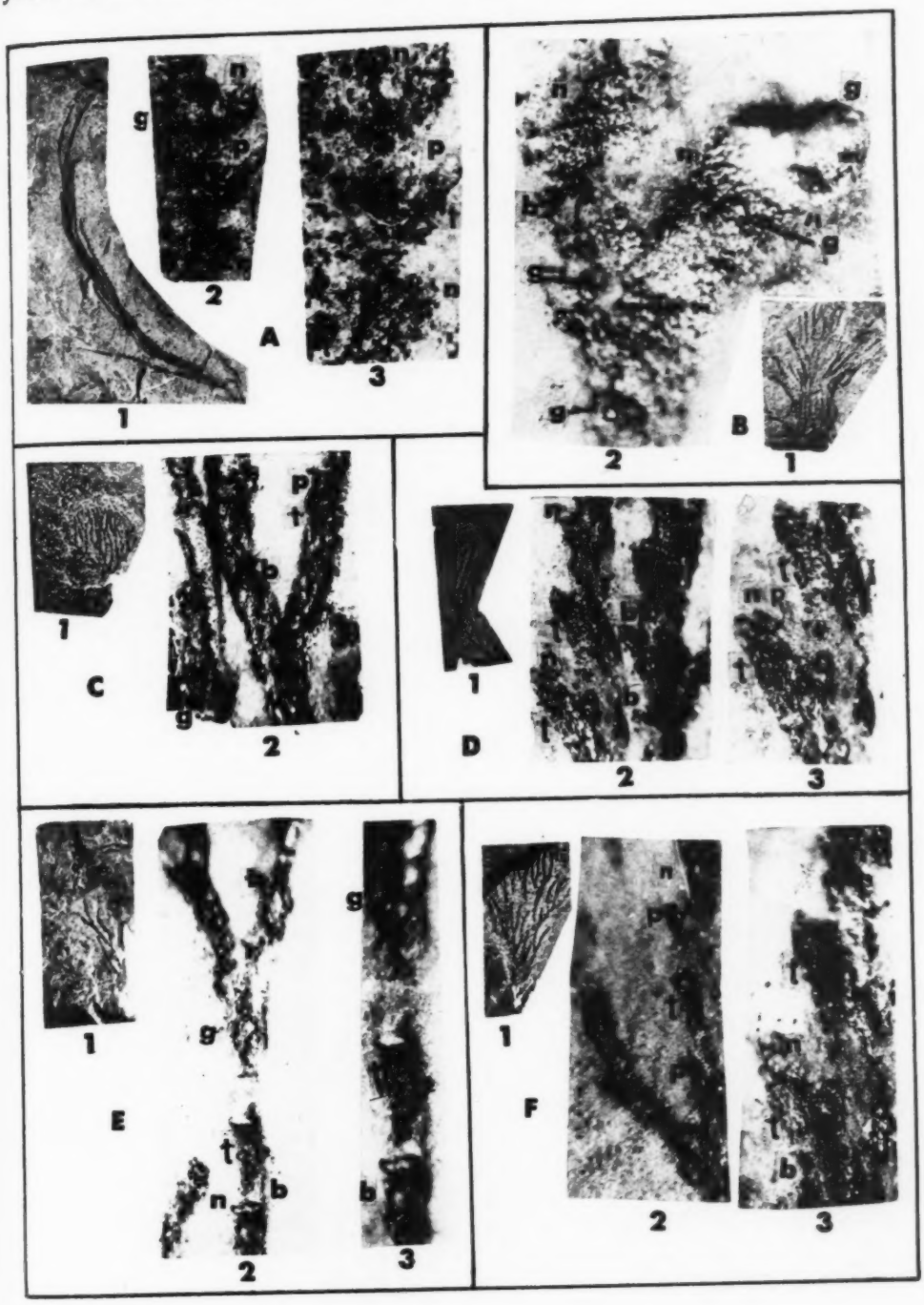
Dendrograptus from Virginia (lower zone)

FIG. *A*—*Dendrograptus edwardsi grattonensis* Decker & Gold, n. var. *A*, holotype. *A1*, colony (×1). *A2*, part of a stipe (×19) showing gonothecae (*g*), calcified polyp (*p*), nematothecae around thecal apertures (*n*). *A3*, part of a stipe (×26) showing thecae (*t*), calcified polyp (*p*), and nematothecae around thecal aperture (*n*).

B,C—*Dendrograptus hallianus moneymakeri* Ruedemann. *B,C*, ideotypes. *B1*, colony (×1). *B2*, part of a stipe (×50) showing 3 gonothecae (*g*), bitheca (*b*), and numerous nematothecae (*n*). *C1*, colony (×1). *C2*, parts of stipes (×17) showing theca (*t*), bithecae (*b*), gonotheca (*g*), and calcified end of polyp protruding from thecal aperture (*p*).

D—*Dendrograptus kindlei* Ruedemann. *D*, ideotype. *D1*, part of a colony (×1). *D2*, part of two stipes (×17) showing thecae (*t*), slender bithecae (*b*), tiny nematothecae (*n*), a calcified polyp below (*p*) with nematothecae around it. *D3* part of a stipe (×26) showing theca (*t*), nematothecae below *n*, and end of calcified polyp below *p*.

E,F—*Dendrograptus thomasi* Ruedemann. *E,F*, ideotypes. *E1*, part of a branching stipe (×15) showing theca (*t*), bithecae (*b*), gonotheca to right of (*g*), and nematothecae to right of (*n*). *E3*, part of a stipe (×26) showing theca (*t*), bitheca (*b*), and gonotheca (*g*). *F1*, colony (×1). *F2*, part of two stipes (×15) showing theca (*t*), and ends of two calcified polyps (*p*). *F3*, part of a stipe (×36) showing theca (*t*), bitheca (*b*), and nematothecae below *n*.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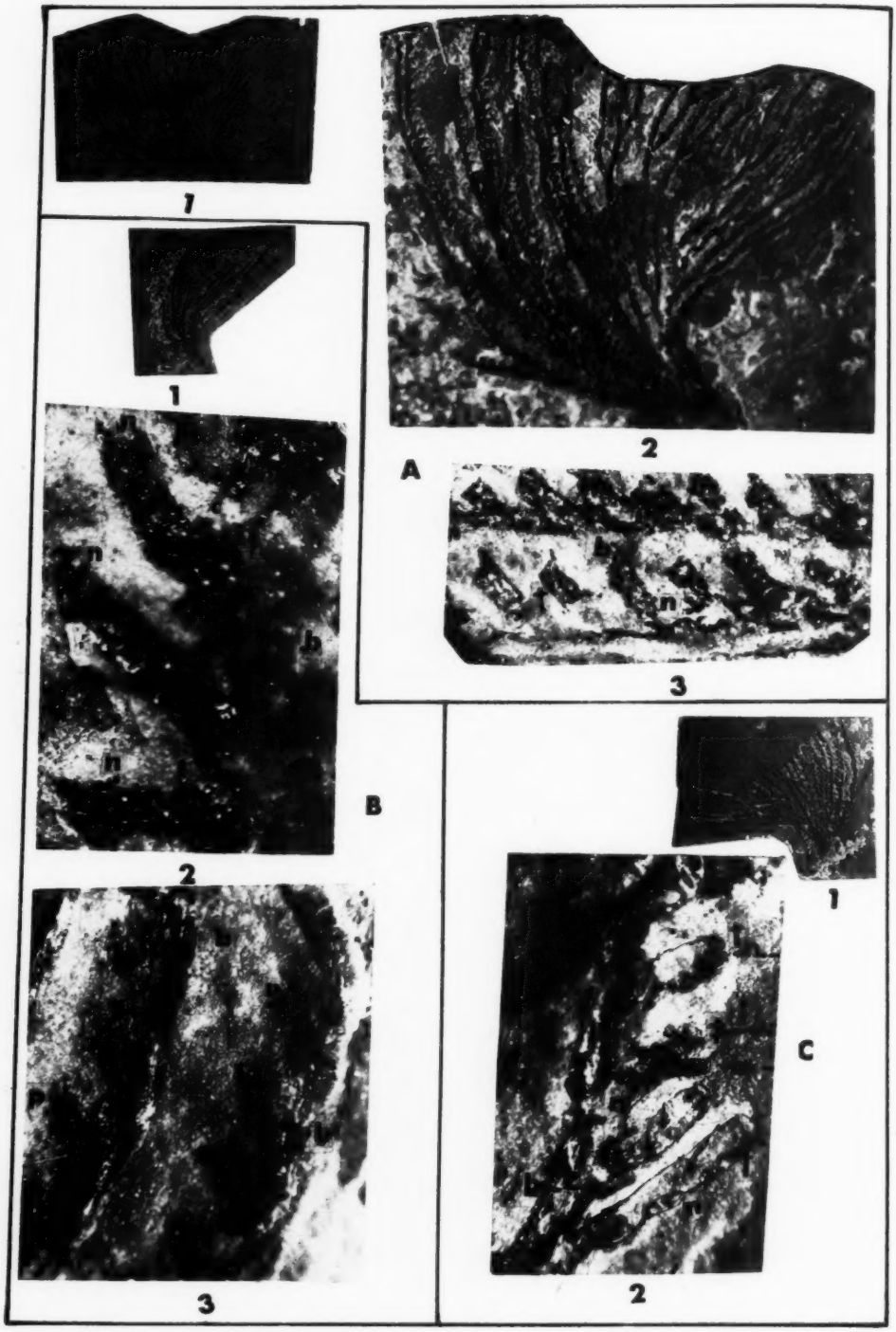
1
1
2
A
n
n
3
n
B
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3
1
C
2

TABLE 1.—TABLE SHOWING UPPER CAMBRIAN GRAPTOLITE ZONES

Note how much higher Minnesota-Wisconsin and Colorado graptolite zones (X) are than those in Virginia, Tennessee, and Texas.

Wisconsin, Minnesota	Virginia, Tennessee	Texas	Colorado	South Dakota	Quebec
Jordan mem.					
Lodi mem. (X)			Peerless fm. Dotsero dol. (X)		
Saint Lawrence mem. Badaxe mem. Hudson mem. Goodenough mem. Ironton mem. Galesville mem.					
Eau Claire mem.	Nolichucky shale (X)	Wilberns fm. (X)		Deadwood fm. (X)	Murphy's Creek fm. (X)
Mt. Simon mem.					

Aspidograptus intermedius Decker & Gold, n. sp.
Callograptus cooperi Decker & Gold, n. sp.
C. semisymmetricus Decker & Gold, n. sp.
C. staufferi var. *bloomeri* Decker & Gold, n. var.
Syndyograptus virginiensis Decker & Gold, n. sp.
Mastigograptus sp.

SYSTEMATIC DESCRIPTIONS

Lower Zone

Animal Kingdom
Sub-kingdom INVERTEBRATA
Phylum COELENTERATA
Special Class GRAPTOLITHINA Bronn, 1846, emend. Lapworth, 1875
Order DENDROIDEA Nicholson, 1872

Family DENDROGRAPTIDAE Roemer (in Frech), 1897
Genus DENDROGRAPTUS Hall, 1858

DENDROGRAPTUS EDWARDSI var. GRATTONENSIS Decker & Gold, n. var.
Pl. 47, figs. A1,2,3

The varietal name *grattonensis* is given for the town of Gratton in southwestern Virginia, near which the Upper Cambrian graptolites occur.

The colony is long, narrow, and curved. It seems to be a complete colony rather than a narrow part of a wider one. It is 50 mm. high and only 3 mm. wide. The stipes are closely set at the rate of 15 or 16 in 10 mm. and most of them are closely parallel. Stipes

EXPLANATION OF PLATE 48

Syrrhipidograptus from Virginia (lower zone)

FIGS. *A–C—Syrrhipidograptus burkesgardenensis* Decker & Gold, n. sp. *A*, holotype. *A1*, colony (×1). *A2*, colony (×2) showing in left half tubular thecae at a high angle with the stipes, also a short downbending stipe at the base. *A3*, part of two stipes (×15) showing tubular thecae at high angle with the stipes (*t*), slender bitheca above *b*, and other bithecae occur at the base of thecae to the right of *b*, nematotheca to the right of *n*, and at apertures of 3 thecae to the left of *n*. *B*, paratype. *B1*, more elongate colony (×1). *B2*, part of a stipe with tubular thecae much enlarged (×36) showing bitheca to left of *b*, three tubular thecae much enlarged, nematothecae (*n*), around the apertures and on the sides of thecae and on stipe. *B3*, two stipes enlarged (×19) showing tubular thecae, bithecae, to left of *b*, calcified polyp at *p*. *C*, paratype. *C1*, colony (×1). (Reverse of *A1*). *C2*, a part of a stipe (×36) showing long tubular thecae (*t*) at high angle with stipe, long slender bitheca to right of lower (*b*), and branching from side of third theca (*t*), nematothecae parallel to side of first theca (*n*) around aperature of fourth theca, and on stipe.

are .5 to .75 mm. wide. Thecae have slight overlap and occur 12 to 13 in 10 mm. Nematothecae (*n*) are shown around apertures of thecae, a hive-shaped gonotheca to the right of *g* in figure A2 and calcified ends of polyps (*p*) extend out of the apertures of the thecae (*t*) (figs. A2, ×19, and A3, ×26).

Remarks.—The species *D. edwardsi* was erected on individual stipes, one as holotype and others as paratypes. The stipes are straight and rigid with pointed thecal apertures extending beyond the margins, and only 8 to 11 occur in 10 mm. or 3 to 4 less than in the new variety.

D. edwardsi var. *major* occurs in large colonies with curved stipes pointing in various directions and having 1 to 3 less thecae in 10 mm. than the new variety *grattonensis*.

Type.—The form described above is designated the holotype for the new variety.

Depository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS HALLIANUS var. MONEYMAKERI Ruedemann
Pl. 47, figs. B1,2; C1,2

Graptolithus hallianus Prout, 1851, p. 187–191, fig. 6.
Dendrograptus hallianus Ruedemann, 1933, p. 314–316, pl. 46, figs. 1–12; pl. 55, fig. 4.
Dendrograptus hallianus moneymakeri Ruedemann, 1947, p. 212, pl. 18, figs. 14,15

The new variety was named for Mr. Moneymaker who owns the Tecoy quarry 7.5 miles west of Knoxville, Tennessee, from which it was collected. The quarry was originally reached by a very circuitous route which made it 10 miles from Knoxville.

Ruedemann's holotype is a beautiful tree-like colony 47 mm. high and 25 mm. wide. Some of the branches rebranch at low angles. The main central stipe is 1.5 mm. wide and the branches 1 mm. Thecae are numerous, 18 in 10 mm. and low, projecting but slightly beyond the margins; bithecae present, but low and difficult to see.

The two ideotypes representing the variety from Virginia include the lower part of a colony 25 mm. high and 18 mm. wide (pl. 47, fig. B1) and the upper part of a stipe (fig. B2, ×50) showing thecae (*t*), bithecae (*b*), gonothecae (*g*), and nematothecae (*n*). A very young colony 14 mm. high and 12 mm. wide is shown (figs. C1, ×1, and C2, ×17) with theca at *t*, bitheca to left of *b*, gonotheca above *g*, and the end of a calcified polyp (*p*) extending slightly out of the aperture of a theca.

Remarks.—The holotype from Tennessee and the ideotypes from Virginia differ greatly from the species *D. hallianus* in form of colony, in shorter interval between branches, and in greater flexibility of branches. The number of thecae in 10 mm. is increased 3 to 6 or to a total of 18 in 10 mm.

Types.—The two forms described above are designated ideotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS KINDLEI Ruedemann
Pl. 47, figs. D1–3

Dendrograptus kindlei Ruedemann, 1933, p. 318,319; pl. 54, fig. 4.
Dendrograptus kindlei Ruedemann, 1947, p. 213, pl. 19, figs. 22–28.

The ideotype from Virginia selected to represent this species is only a small part of a colony 15 mm. high and 3 mm. wide, but it has many of the characteristics of Ruedemann's holotype. It has the same height with rigidly flexed stipes of .5 mm. in width and an overlap of thecae of about ½, same number of thecae, 16 in 10 mm. Thecae in side view extend beyond margin of stipes with ventral margin concave. Thecae (*t*), bithecae (*b*), and nematothecae (*n*) are shown at higher magnification (pl. 47, fig. D2, ×17; D3, ×26).

Remarks.—Though in a statement about the holotype Ruedemann spoke of the apparent absence of bithecae, several of the narrow elongate structures shown in his (1933, pl. 53, fig. 5) figure may well represent bithecae, and much enlarged structures at the bifurcation of the branches, gonothecae. Ruedemann's specimens of this species came from 1.5 miles west of Corner-of-the-Beach, Gaspe County, Quebec.

Type.—The form described above is chosen as an ideotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS THOMASI Ruedemann
Pl. 47, figs. E1,2,3; F1,2,3

Dendrograptus thomasi Ruedemann, 1933, p. 317, 318; pl. 51, figs. 1–4.
Dendrograptus thomasi Decker, 1936, p. 304.

Dendrograptus thomasi Decker, 1945, p. 26, pl. 2, figs. 5,6; pl. 7, fig. 5; pl. 10, fig. 8.
Dendrograptus thomasi Ruedemann, 1947, p. 213–214, pl. 18, figs. 20–26; pl. 19, figs. 1–4.

Characteristically this species occurs in small rather openly branched colonies with thin stipes branching at short intervals with curved branches and thecae occurring 16 in 10 mm.

Two Virginia ideotypes have been chosen, the first a small part of a colony 15 mm. high and 4 mm. wide (pl. 47, figs. E1, ×1; E2, ×15; E3, ×26). It has the narrow curved stipes .25 mm. wide and (fig. E2) shows thecae (*t*), bithecae (*b*), hive-like gonothecae (*g*), and tiny nematothecae near *n*. Another larger parts of a colony (figs. F1,2, ×15; 3, ×36) has a height of 25 mm. and width of 13 mm. with branches .25 mm. wide and thecae occurring 16 to 18 in 10 mm.

Pl. 47, fig. F2, ×15, shows a dark calcified end of a polyp extending a short distance out of the thecal aperture at the right of upper *p*, a long, slender, light calcified bithecal polyp to right of lower *p* around which nematocysts are preserved, and a regular theca at *t*. Pl. 47, fig. F3, ×36, shows thecae at *t*, bitheca at *b*, and nematothecae around aperture below *n* and scattered on the surface of the stipe.

Remarks.—Ruedemann has shown two small colonies of this species from the Deadwood formation from the wall of Whitewood Canyon, South Dakota. Also, the writer found two colonies and parts of two others from the Wilberns formation near Mason, Texas. These all show the characteristics of the species very well.

Types.—The two forms described above were chosen as ideotypes of this species.

Respository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus SYRRHIPIDOGRAPTUS Poulsen, 1924

The new genus was introduced by Poulsen (1924, p. 253–257) from the Ordovician from the Island of Bormholm northeast of Denmark, and the genotype was described as *Syrrhipidograptus nathorsti* Poulsen. The new genus differs from all others in having the bases of three branching colonies of different sizes attached to a heavier horizontal stipe, though the base of one is separated slightly from that stipe. Also, the fan-shaped colonies have a marginal stipe on each side from which arise the branches inside them. Tubular thecae twice as long as wide set at an angle of 60 degrees protrude from the stipes toward the center of the colonies.

SYRRHIPIDOGRAPTUS BURKESGARDENENSIS
Decker & Gold n. sp.
Pl. 48, figs. A1,2,3; B1,2,3; C1,2,3

The trivial name is given the species for the Burkes Garden quadrangle in which the graptolites occur near Gratton, Virginia. Three specimens are used in describing the species, the largest one as holotype (pl. 48, figs. A1,2,3) and two as paratypes, one an elongate colony (B1, ×1; B2, ×36; and B3, ×19), and the other representing part of a reverse of the holotype (figs. C1, ×1, and C2, ×36).

The fan-shaped colony (pl. 48, figs. A1, ×1, and A2, ×2) is taken as the holotype, being 23 mm. high and 31 mm. wide. The outer stipe at the left of the colony is 35 mm. long, and the one at the right 27 mm. long. A basal stipe extends down for a short distance from the base of the colony, possibly for attachment to a horizontal stipe which is not preserved here. Branching is rare in the left half of the colony, but bifurcation takes place at intervals of 5, 6, 8 and 10 mm. in the right half. Stipes are .5 to .6 mm. wide, and thecae occur 14 in 10 mm. Thecae are tubular, and are 1.5 to 2 mm. long and protrude from the stipes at an angle of about 60 degrees. In figure A2 (×2) the thecae show well in the left half of the colony.

Part of two stipes of the holotype are shown ×15 in figure A3 with thecae standing at an angle of 60 degrees. A bitheca shows above *b* and at the bases of the two thecae to the right of *b*. A nematotheca shows at the right of *n* and a single one is preserved at the apertures of two thecae at the lower left.

The paratype shown in B1 is much like the one illustrated by Poulsen (1924, p. 254, fig. 7), being longer and narrower than the form shown in A1) with a longer basal connectional stipe. However, it has stipes of the same width and similar elongate protruding thecae. In figure B3 elongate tubular thecae are shown (×19) at a high angle

with the stipes. An elongate slender bitheca shows at upper end of left stipe to the left of *b* and one to the left of *b* on the right side of the right stipe, and the calcified end of a polyp protrudes from the thecal aperture at *p*.

In figure B2 (×36) three enlarged tubular thecae are shown with nematothecae around the apertures and numerous ones making their surfaces irregular and rough. A bitheca shows at *b*, and a hive-shaped gonotheca at *g* at the right edge.

A second paratype shown in figures C1 (×1) and C2 (×36) represents part of the reverse of specimens illustrated in figures A1 and A2. The preserved part of the colony is 25 mm. high and 25 mm. wide. In figure C1 the tubular thecae show better on the right side than on the left, a normal position for them as reverse of the holotype. Also, the general shape, curvature, width of stipes, and character of the thecae seem to mark it as the reverse of A1.

In figure C2 the elongate tubular thecae (*t*) show well with round apertures, with some nematothecae (*n*) parallel and others at right angles to the thecal surfaces, and around aperture of the fourth one from bottom. A bitheca (*b*) occurs at the base of the second theca and high on the side of the third one.

Remarks.—As Poulsen failed to find bithecae on S. *nathorsti*, he placed it under *Graptoloidea*. He kindly sent the writer a duplicate specimen which is too dim to be photographed, but with bright light under high magnification (×36) part of one stipe seemed to show two narrow elongate structures thought to be bithecae. The Upper Cambrian Virginia species showing bithecae, gonothecae, and nematothecae is clearly a dendroid form.

Types.—The form represented in figure A1 is taken as the holotype and forms represented in in figures B1 and C1 are considered paratypes.

Respository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus ASPIDOGRAPTUS Bulman, 1934

ASPIDOGRAPTUS INTERMEDIUS Decker & Gold, n. sp.

Pl. 49, fig. A1

The trivial name *intermedius* is used because this form is intermediate in size and shape between *Aspidograptus implicatus* and *A. minor* described and illustrated by Bulman (1934, p. 69–74, pl. 9, figs. 8–12; pl. 10, figs. 1–3; pl. 10, figs. 4,5; text-fig. 38). The lower part of the colony is wanting and only a small part is preserved of the semicircular stipe from which the other stipes radiated. The central lower part of the colony was destroyed by a circular excavation above which about three-fourths of the colony is preserved. Below the lower edge of the excavation, three less distinct branching stipes indicate the position of the lower part of the colony, so the original colony had a diameter of 25 to 30 mm. while Bulman's larger form measures 40 to 50 mm. across, and the smaller one 20 to 22 mm. across.

Stipes are .4 to .5 mm. wide and the bifurcating interval varies from 2 to 9 mm., where uncompressed, thecae are tubular, tapering slightly toward the apertures. They occur 16 to 18 in 10 mm. and have nematothecae around the apertures, on the sides of the thecae, and on the surface of the stipes. Elongate bithecae occur, and a few gonothecae show at the bifurcation of branches. The calcified ends of two polyps protrude from the apertures of the thecae. It is interesting to find these special structures on *Aspidograptus* as well as on *Syrrhipidograptus* and various species of *Dendrograptus*, *Callograptus*, and *Dictyonema*.

Remarks.—Bulman's *Aspidograptus implicatus* and *A. minor* came from the Lower Ordovician *Didymograptus extensus* zone from South Wales and Shropshire, England. As compared with Bulman's specimens *A. intermedius* differs not only in size, but has narrower and less curved stipes, and 2 less thecae in 10 mm.

Horizon and Locality.—This new species came from the lower of two graptolite zones in the upper part of the Nolichucky shale upper Cambrian near Gratton, Virginia. Fragments of a colony of *Aspidograptus* were found by the senior writer (1945, p. 35, pl. 10, figs. 9–14) near Mason, Texas.

Type.—The figured specimen is the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus CALLOGRAPTUS Hall 1865

CALLOGRAPTUS COOPERI, Decker & Gold, n. sp.

Pl. 49, figs. B1 ×1; B2 ×19

The trivial name is given to this species in honor of Byron Cooper, who was supervising the geologic work in the Burkes Garden quadrangle when the graptolites were found near Gratton, Virginia. He took the writer to that locality and helped to make the early collections. He (1944, p. 22) had already identified and listed 5 species of the Upper Cambrian graptolites.

The colony is fan-shaped with a short stem at the base. It is 25 mm. high and 20 mm. wide with ends of some of the stipes broken off on the right side. The stipes radiate from a point near the base with 9 occurring in the space of 10 mm. Bifurcating intervals are 1 to 2 mm. in the lower part, but increase to 4 mm. higher up. Stipes range from .5 to .8 mm. wide. Thecae are tubular with round apertures, and occur 16 to 18 in 10 mm. In figure B2 a long narrow bitheca occurs to the right of *b*, a gonotheca to the right of *g*, a theca at *t*, and nematothecae near *n*.

Remarks.—The stipes radiate from a point above the base to make a fan-shaped colony differing from all other species. A colony from Tennessee is described below and illustrated in pl. 56, figs B1,2, C1.

Type.—The specimen described above is the holotype.

Respository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLOGRAPTUS SEMISYMMETRICUS, Decker & Gold n. sp.

Pl. 49, figs. C1 ×1; C2 ×19

This seems to be an elongate, narrow colony instead of part of one. It is rather symmetrical, so is given the trivial name of *semisymmetricus*, though bifurcation intervals vary, as does also the bifurcation angle.

The colony is long and narrow, 29 mm. high and 7 mm. wide. The stipes are less than .25 mm. wide and openly spaced, 8 in 10 mm. The bifurcation angle for most of the colony is 10° to 12°, but at the right and in the middle near the top it is increased to 20° to 30°. Also, for most of the colony, the bifurcation space is 5 to 7 mm., while in the middle near the top and at the right, the bifurcation intervals are shortened to 1, 2, and 3 mm. Thecae are tubular with round apertures, short, occurring 18 to 19 in 10 mm. without overlap. Bithecae (*b*) occur with some of the thecae, and enlarged conical gonothecae occur below the place of bifurcation of some of the branches. Nematothecae project beyond the surfaces of the stipes, and they occur also around the apertures of the thecae.

Remarks.—This appears to be a young colony, very narrow stipes with open spacing, with bifurcation intervals and angles differing in various parts of the colony.

Type.—The form described above is the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLOGRAPTUS STAUFFERI var. BLOOMERI Decker & Gold, n. var.

Pl. 49, figs. D1,2; E1,2,3; F1,2; G1,2.

The trivial varietal name *bloomeri* is given in honor of Robert O. Bloomer, who discovered the lower main Upper Cambrian graptolite zone 1.5 miles east of Gratton, Virginia. The graptolites were discovered while he was assisting Byron Cooper in field work on the geology of the Burkes Garden quadrangle in southwestern Virginia. This variety is represented by the largest number of well-preserved specimens in the collection. Several of the colonies have been partially or completely pyritized.

The colony shown in pl. 49, figs. D1, D2, is chosen as the holotype and three others as paratypes shown in figures E1,2,3; F1,2; and G1,2. The holotype shown in figure D1 represents about three-fourths of a colony, with about one-fourth absent along the right side. It is 30 mm. high and 21 mm. wide. The stipes are .75 mm. wide, closely parallel and occur 12 in the space of 10 mm. Thecae are elongate, cylindrical, with round apertures, and occur 14 to 16 in 10 mm., with slight overlap up to one-fourth their length. Figure D2 (×26) shows part of a stipe with tubular theca well-developed (*t*), light colored bitheca to the left of *b*, and nematothecae (*n*) around the thecal apertures and on their sides. They occur also on the surface of the stipes, as at lower right edge.

One of the paratypes is shown pl. 49, figs. E1, ×1; E2, ×2; and E3, ×26. The way in which the stipes are arranged in figures E1 and E2 suggest that it was infundibuliform, or funnel-shaped. The colony has a height of 20 mm. and a width, or diameter, of 17 mm. The stipes are .5 mm. wide, bifurcate at a very low angle at intervals of about 5 mm., and soon become closely parallel, being spaced 10 in 10 mm. Thecae occur 12–13 in 10 mm. with small overlap. The bare space in the center of the colony may have been partly filled as pieces of two broken stipes show in the lower part of it in E2, yet such a space may have been characteristic, as a narrower one shows near the central top of figure D1. The part of a stipe shown in figure E3 (×26) shows an enlarged hive-shaped gonotheca at the base above *g*, a bitheca to the right of *b*, a long narrow calcified polyp with nematotheca around it below *p*, and nematothecae protruding above the surface of the stipe near *n*, and they show also on the surface farther down.

A second paratype is shown in figures F1 (×1) and F2 (×17). The colony shown in F1 is quite similar to those in D1 and E1, but lacks the central division in them, or the bare space. The part of colony preserved is 18 mm. high and 18 mm. wide at the top. Stipes are very narrow, less than .5 mm. wide, and closely parallel in the left half, with 12 occurring in the space of 10 mm., and in that part they bifurcate infrequently, whereas at the upper right they bifurcate at short intervals, and bend toward the right. Thecae occur 14 to 16 in 10 mm. In figure F2 (×17) a gonotheca shows at the bottom to the right of *g*, bitheca to the right of *b*, and nematothecae to the right of *n* along the stipe.

A third paratype is shown in figure G1 (×1) and G2 (×36). It is only a small part of a colony 20 mm. high and 5 mm. wide, but it is beautifully preserved. Stipes are narrow and nearly parallel. Thecae are preserved in three dimensions. They are tubular, with round apertures, and occur 16 in 10 mm. Thecae and bithecae show closely associated, and several large barrel-shaped gonothecae occur along the stipes with nematothecae around their apertures.

Figure G2 (×36) shows tubular thecae (*t*), elongate narrow bithecae (*b*), and nematothecae to the right of *n* on the surface of the stipes.

Remarks.—The new variety differs from *C. staufferi* in having the stipes more closely set, in a different shaped colony, with 2 to 4 more thecae in 10 mm.

Type.—This specimen in pl. 49, fig. D1, is designated the holotype. The three paratypes are the specimens shown in E1, F1, and G1.

REPOSITORY.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus SYNDYOGRAPTUS Ruedemann, 1908

SYNDYOGRAPTUS VIRGINIENSIS Decker & Gold, n. sp.

Pl. 49, figs. H1,2,3

The trivial name *virginiensis* is given to this species because it is from Virginia instead of New York or Washington, where the other two species were found.

The new species is represented by the right half of a rather flattened somewhat ovoid colony, consisting of a main evenly curved main stipe at the right from the inner concave margin of which secondary stipes apparently hang as a series of branches some of which bifurcate to form tertiary branches. The partial colony is 17 mm. high and 7 mm. wide. One of the secondary branches is broken and a part of it moved out of its normal position, and another one is broken and part of it rotated about 180 degrees, so that thecae on it point upward, or in opposite direction to normal downward pointing thecae. The stipes are .33 to .5 mm. wide. Thecae number 12 in 10 mm. on the main stipe, and 24 in 10 mm. on the inner branches.

REMARKS.—This new Upper Cambrian species is most like Ruedemann's (1947, p. 374, pl. 61, figs. 24,25) *Syndyograptus bridgei* from the black Ordovician shale from Metaline Falls, Washington. However, it differs from the Ordovician species in having the main right stipe more deeply and more evenly curved, and in having much shorter thecae, 12 to 24 in 10 mm. instead of 10 to 12 in 10 mm. The most significant and outstanding difference is in the simplicity and the complexity of the thecae. Ruedemann's species has thecae of a single kind and was placed under *Graptoloidea*, but the new spe-

cies (pl. 49, fig. H3) magnified (×17) shows a hive-shaped gonotheca (*g*) near the top, a bitheca to the left of *b*, an elongate downward pointing theca to the right of *t*, and nematothecae to the left of *n* along the left margin. This complexity of thecae would seem to place it under *Dendroidea*.

Type.—The form described above is chosen as holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus MASTIGOGRAPTUS Ruedemann, 1908

MASTIGOGRAPTUS sp.

Pl. 49, fig. I1

A small poorly preserved, simple, branching specimen is shown in which the stipes resemble those of *Mastigograptus*. This fragment is more like the smaller two fragments of *Mastigograptus* shown by Ruedemann (1933, p. 326, pl. 52, figs. 6,7) from the Upper Cambrian Trempealeau formation from Richland Center, Richland County, Wisconsin.

Upper Zone

The upper zone of the Upper Cambrian graptolites near Gratton, Virginia occurs 30 feet above the lower one, and contains the following species and varieties.

Dendrograptus sp. cf. *D. edwardsi* Ruedemann
Dendrograptus edwardsi var. *grattonensis* Decker & Gold, n. var.
Dendrograptus flabellites var. *spreadatus* Decker & Gold, n. var.
Dendrograptus hallianus var. *moneymakeri* Ruedemann
Dendrograptus hickorius Decker & Gold, n. sp.
Dendrograptus kindlei Ruedemann
Dendrograptus monoforsythiatus Decker & Gold, n. sp.
Callograptus cooperi Decker & Gold, n. sp.
Callograptus multibifurcatus Decker & Gold, n. sp.
Acanthograptus browni Decker & Gold, n. sp.
Callodendrograptus sellardsi Decker
Callodendrograptus sellardsi var. *expansus* Decker
Palaeodictyota sp. (not illustrated)

Genus DENDROGRAPTUS Hall, 1858

DENDROGRAPTUS sp. cf. D. EDWARDSI Ruedemann

Described but not illustrated

Dendrograptus edwardsi Ruedemann, 1933, p. 316,317, pl. 47, figs. 2,4–8; pl. 49, figs. 3,4,6.
Dendrograptus edwardsi Decker, 1936, p. 304.
Dendrograptus edwardsi Ruedemann, 1947, p. 210.

The ideotype chosen has rigidly branching stipes in part of a colony which is 14 mm. high and 8 mm. wide. Stipes are .75 to 1 mm. wide. The branches do not show thecae in side view, but a fragment apparently broken from the top has thecae 8 in 10 mm. extending clearly beyond the margin of the stipe with overlap $\frac{1}{4}$ of their length or less.

Ruedemann's holotype of this species is based on a part of a stipe (1933, pl. 47, figs. 4,8) 6 mm. long and paratypes (pl. 47, figs. 2,5–7; pl. 49, figs. 3,4,6). These show thecae in side view extending distinctly beyond the margins of the stipes, where thecal overlap varies from small amount to about one-half.

Remarks.—The species *edwardsi* differs from *D. edwardsi* var. *major* in having narrower, straighter stipes with thecae a little longer, extending more distinctly beyond the margin of the stipes.

Type.—The form described above is designated an ideotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS EDWARDSI var. GRATTONENSIS Decker & Gold, n. var.

Pl. 50, figs. A1,2

This narrow elongate variety is described above. A specimen discovered within the upper zone is poorly preserved and difficult to photograph. It is 48 mm. high and 7 mm. wide with 8 stipes occurring in the space of 10 mm., and they are .5 mm. wide. Thecae occur 12–14 in 10 mm. with slight overlap. The enlargement (×19) in fig. A2 shows a theca to the left of *t*, bithecae to the right of *b* on each stipe, 2 hive-shaped gonotheca (g), and tiny nematothecae on the stipe to the right of *n*.

Remarks.—This colony in the upper zone is shorter, wider, and less curved than the one in the lower zone. The stipes are a littler wider and more openly spaced than those in the lower zone. The graptolites occur in a more indurated brownish gray shale from which they differ but slightly in color.

Type.—This specimen in the upper zone is chosen as a paratype.

Respository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS FLABELLITES var. SPREADATUS Decker & Gold, n. var.
Described but not illustrated

Dendrograptus hallianus Ruedemann, 1933, pl. 46, figs. 1,5; pl. 47, fig. 3; pl. 48, fig. 1.
Dendrograptus flabellites Ruedemann, 1947, p. 211, pl. 18, figs. 16–19.

This species was erected by Ruedemann to contain several forms with broad short thecae which he had included with the much narrower *Dendrograptus hallianus*, and he (1947, pl. 18, figs. 16,18) has illustrated the species with two forms differing greatly in shape—one low, very broad, bushy form with broad short stipes and a much taller tree-like form with a large elongate primary stipe from which short closely spaced wide branches arise. Stipes of the new variety spread more widely and openly.

Two very small parts of colonies are described for this species. The first is a small fragment 9 mm. high with two short nearly parallel branches at the top where the thecae are rather short and broad, exhibiting a bitheca, a hive-shaped gonotheca, and nematothecae.

On the slab with this species some parts of a colony of *Palaeodictyota* can be seen under a magnification of (×36) with its typical nearly circular fenestrules shown for the first time in the Upper Cambrian. This genus has been described from the upper Ordovician Ottosee shale and from the Silurian formations, including the Niagaran rocks, near Hamilton, Ontario.

A second representative of *Dendrograptus flabellites spreadatus* Decker & Gold, n. var., occurs at this horizon where it is 11 mm. high and 8 mm. wide, consisting of a main stipe with several short branches. In this form thecae are short and broad, and an elongate slender bitheca, nemothecae, and a gonotheca are present.

Remarks.—While these specimens have short, broad thecae, the stipes are more openly branched than is common with this species.

Types.—These two parts of colonies are designated cotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS HALLIANUS var. MONEYMAKERI Ruedemann
Pl. 50, figs., B1,2; C1,2; D1,2

Dendrograptus hallianus var. *moneymakeri* Ruedemann, 1947, p. 212, pl. 18, figs. 14,15.

This variety, which was described by Ruedemann (1947, p. 212) from the Nolichucky shale from Tecoy Quarry 7.5 miles west of Knoxville, Tennessee, and now in the lower of the two zones near Gratton, Virginia, by the writer (pl. 47, figs. B1,2; C1,2; D1,2), occurs also in the upper zone.

EXPLANATION OF PLATE 49

Aspidograptus and *Callograptus* from Virginia (lower zone)

FIG. *A*—*Aspidograptus intermedius* Decker & Gold, n. sp. *A*, holotype. *A1*, colony (×1) with basal part gone from rounded excavation.

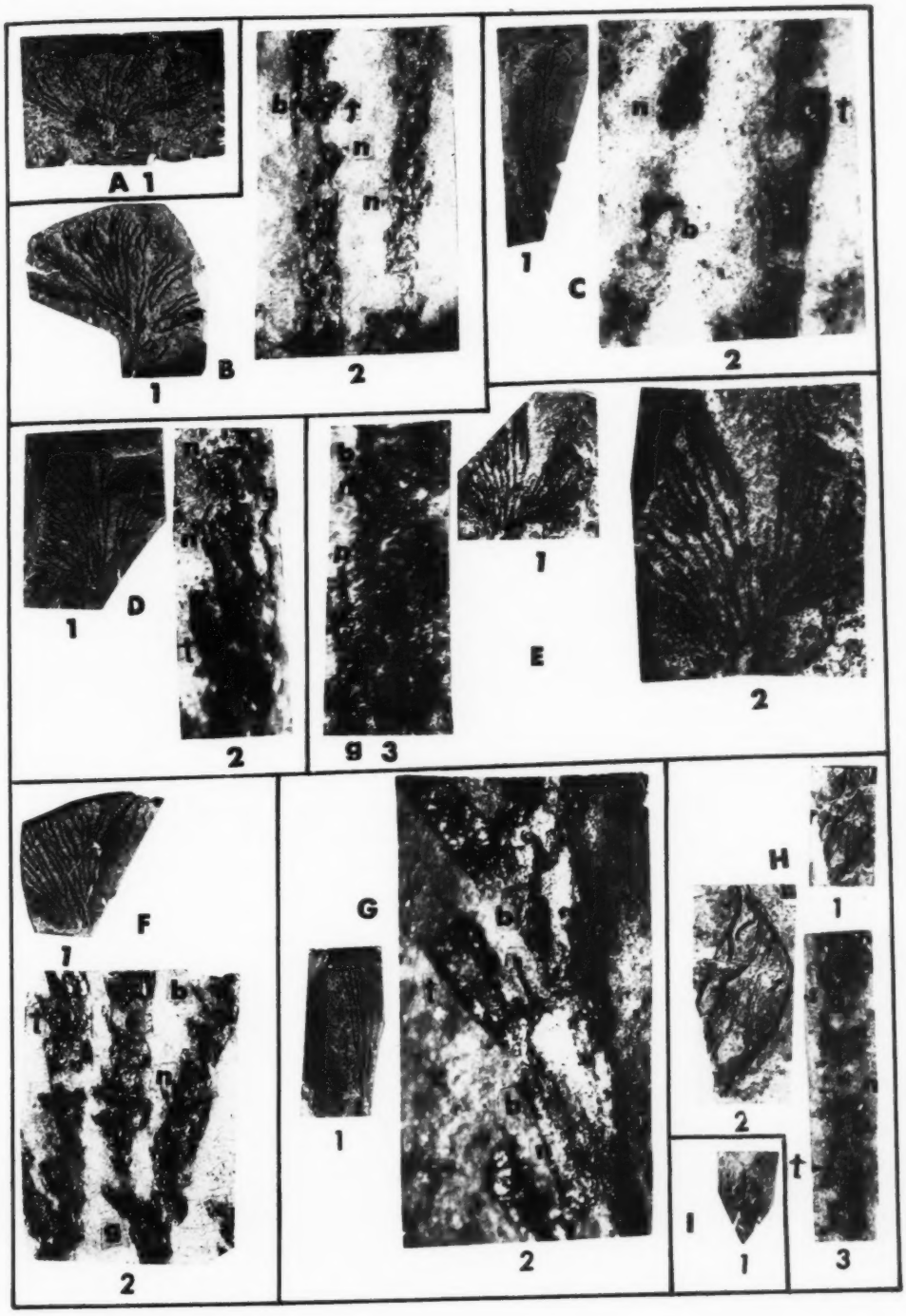
B—*Callograptus cooperi* Decker & Gold, n. sp. *B*, holotype. *B1*, colony (×1). *B2*, two stipes (×19) showing theca (*t*), bitheca (*b*), nematothecae (*n*), gonotheca (*g*).

C—*Callograptus semisymmetricus* Decker & Gold, n. sp. *C*, holotype. *C1*, colony (×1). *C2*, part of 2 stipes (×19) showing theca (*t*), bitheca (*b*), nematothecae protruding beyond the margin of stipe.

D–G—*Callograptus staufferi* var. *bloomeri* Decker & Gold, n. var. *D*, holotype. *D1*, colony (×1). *D2*, part of a stipe (×26) showing theca (*t*), bitheca to left of *b*, nematothecae (*n*) around thecal apertures and on stipe. *E*, paratype. *E1*, second colony (×1). *E2*, colony (×2). *E3*, part of a stipe (×26) showing bitheca to right of *b*, nematothecae (*n*) along surface of stipe, a calcified polyp below (*p*). *F*, paratype. *F1*, a third colony (×1). *F2*, three stipes (×17) showing theca (*t*), bitheca (*b*), gonotheca to right of *g*, nematothecae on stipes both sides of (*n*). *G*, paratype. *G1*, a fourth colony (×1). *G2*, part of a stipe (×36) showing enlarged theca (*t*), long tubular bitheca (*b*), nematothecae on surface of thecae and stipes (*n*).

H—*Syndyograptus virginiensis* Decker & Gold, n. sp. *H*, holotype. *H1*, one half of a colony (×1). *H2*, one half of a colony (×2). *H3*, part of stipe (×17) showing theca (*t*), bitheca (*b*), gonotheca (*g*), nematothecae (*n*) on surface of stipe.

I—*Mastigograptus* sp. Fragment of a colony (×1) showing a few short, plain branches.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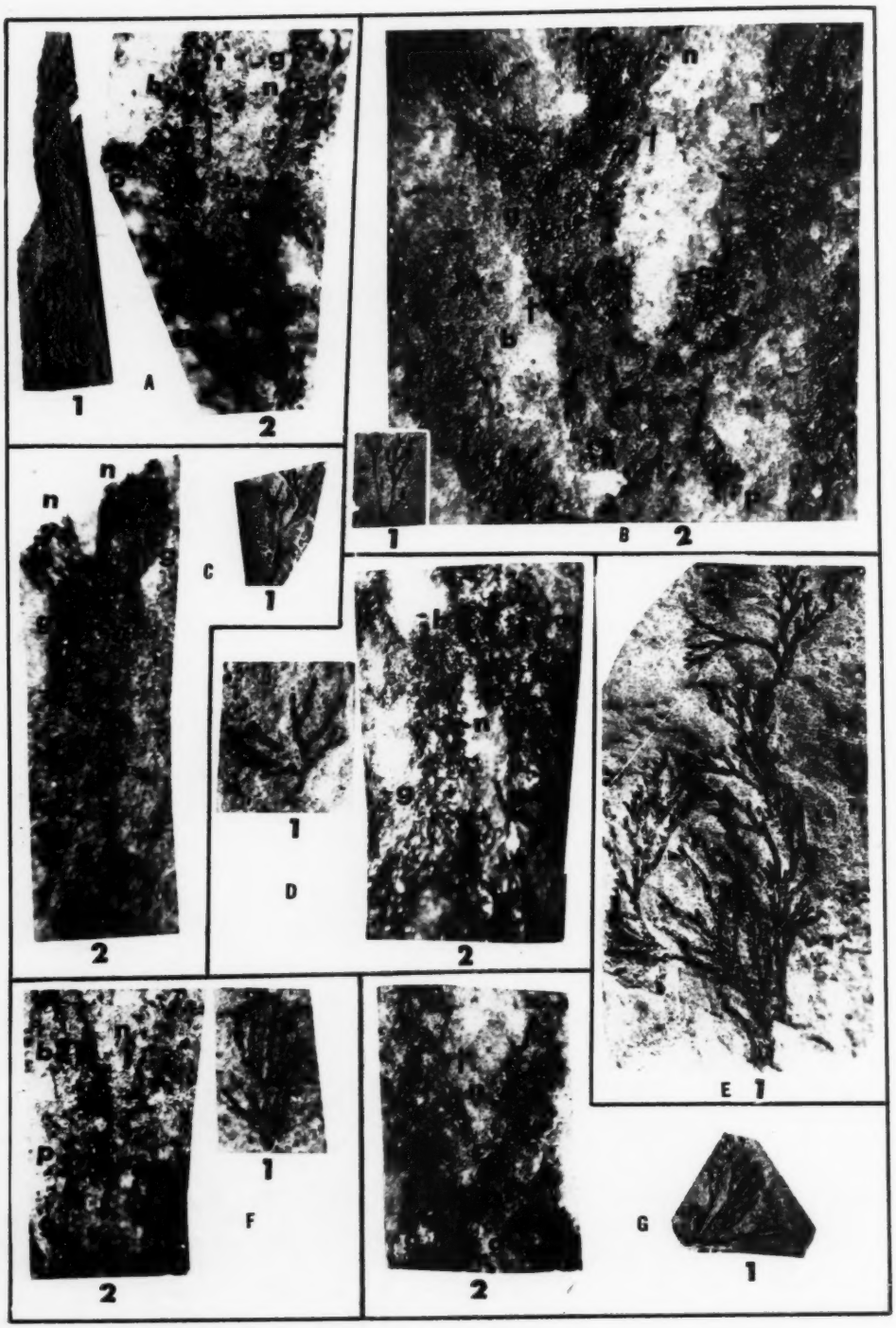
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The holotype of the variety from the Tecoy Quarry in Tennessee is a beautiful tree-like colony 46 mm. high and 21 mm. wide. Parts of three colonies are chosen to represent the variety from the upper of the two Virginia zones. The first one is the small part of a colony (pl. 50, figs. B1,2), 14 mm. high and 8 mm. wide, rather openly branched. The stipes vary from .5 to 1 mm. in width. Bifurcation angle is small and bifurcation intervals vary from 2 to 4 mm. Thecae are short occurring 18 in 10 mm. The part of a colony (B2, ×36) shows a theca to the left of the upper *t* and to the right of the lower one, a slender bitheca to the left of *b*, a large hive-shaped gonotheca to the right of *g*, nematothecae show on the stipes near *n* and elsewhere, and a large calcified polyp with swollen end with nematocysts on the surface at *p*.

A second part of a colony (pl. 50, figs. C1,2) is 18 mm. high and 10 mm. wide. The main stipe is 1.3 mm. wide and the branches .5 mm. wide, the bifurcation interval is 2 to 4 mm., and thecae occur 18 in 10 mm. A single stipe (fig. C2, ×40) shows a large hive-shaped gonotheca to the right of the lower *g*, and to the left of the upper *g*, nematothecae occur to the right and below the upper *n* and show very well around the apertural end of a theca below the lower *n*.

A part of a third colony (fig. D1, ×2) represents only some top branches of a colony, 9 mm. high and 9 mm. wide. The stipes are about .5 mm. wide and the bifurcation intervals are short, only 1 to 2 mm., and thecae occur 18 in 10 mm.

The two stipes shown in figure D2 (×26) show large hive-shaped gonothecae to the right of the lower *g*, and to the left of the upper one, a bitheca at *b*, and nematothecae along the stipe either side of *n*.

Remarks.—This variety described first from Tennessee occurs in both of the Virginia zones, but is not known elsewhere.

Types.—The three forms described above are designated ideotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS HICORIUS Decker & Gold, n. sp.
Pl. 50, fig. E1

The trivial name *hicorius* is given to this species because it braches in a manner similar to a hickory tree. It is shown enlarged ×2, because the details show much clearer than at natural-size. It is 36 mm. high and 16 mm. wide. The largest stipes are 1.5 mm. wide and the branches .5 to 1 mm. wide. All of the larger branches are openly curved. In side view the thecae show a sharp apertural edge extending beyond the margin of the stipes. They occur 12 to 16 in 10 mm. Higher magnification (×36) shows thecae, bithecae, gonothecae,

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EXPLANATION OF PLATE 50

Dendrograptus from Virginia (upper zone)

FIG. *A*—*Dendrograptus edwardsi grattonensis* Decker & Gold, n. var. *A*, paratype. *A1*, elongate, slender colony (×1). *A2*, part of two stipes (×19) showing gonotheca near bottom (*g*), bithecae to right of *b* on the two stipes, nematothecae (*n*), on stipe to right of *n* and on stipe further down, calcified polyp above *p*.

B–D—*Dendrograptus hallianus moneymakeri* Ruedemann. *B,C,* and *D*, ideotypes. *B1*, small part of colony (×1). *B2*, part of branching stipes (×36) showing theca to left of upper *t* and to right of lower *t*, elongate bitheca (*b*), gonotheca to right of *g*, nematothecae on stipes near *n*, and calcified polyp with enlarged end at *p*. *C1*, part of a second colony (×1). *C2*, enlarged stipe (×40) showing two large gonothecae (*g*) and protruding nematothecae near *n*. *D1*, small part of third colony (×2). *D2*, part of two stipes (×26) showing slender bitheca to the right of *b*, gonothecae to left of upper *g*, and to right of lower *g*.

E—*Dendrograptus hicorius* Decker & Gold, n. sp. *E*, holotype. *E1*, beautiful tree-like colony (×2) showing thecae extending beyond the margin of some stipes.

F—*Dendrograptus kindlei* Ruedemann. *F*, ideotype. *F1*, part of small colony (×2). *F2*, part of two stipes (×20) showing bitheca to right of *b*, two calcified polyps to the right of *p*, a slender bithecal one and a thecal one, both having numerous nematocysts around them.

G—*Dendrograptus monoforsythiatus* Decker & Gold, n. sp. *G*, holotype. *G1*, colony (×1). *G2*, part of two stipes (×19), showing gonotheca (*g*) at lower right, theca (*t*), and nematothecae on stipe to left of *n*.

and especially nematothecae in great numbers.

Remarks.—In general form this new species resembles closely that of *Dendrograptus hallianus moneymakeri* Ruedemann from the Nolichucky shale at Tecoy quarry 7.5 miles west of Knoxville, Tennessee, but it differs in having much more open braching and in having larger thecae with 4 to 6 less in 10 mm., 12 to 14 instead of 18 thecae in 10 mm.

Type.—The form described above is designated the holotype.

Respository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus kindlei Ruedemann
Pl. 50, figs. F1,2

Dendrograptus kindlei Ruedemann, 1933, p. 318–319, pl. 53, fig. 5; pl. 54, fig. 4.
Dendrograptus kindlei Ruedemann, 1947, p. 213, figs. 22–28.

The colony chosen to represent this species in the upper zone is 12 mm. high and 7.5 mm. wide. The stipes curve openly and are .5 mm. wide, they are spaced 5 in 5 mm., or 10 in 10 mm. Branching is largely from a diagonal stipe at the right, as in Ruedemann's form (1933, pl. 53, fig. 5) with very sparse branching above. Thecae short, 16 in 10 mm. Figure F1 is enlarged ×2 and F2 ×20. In figure F2 to the right of *b*, a calcified bithecal polyp protrudes from the aperture of a bitheca, at the right of *p* a calcified polyp has numerous nematocysts around it, and small nematothecae occur on the stipe either side of *n*.

Remarks.—This form is much like one of those illustrated by Ruedemann from Gaspe County, Quebec, as referred to just above.

Type.—The form described above is designated an ideotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus monoforsythiatus
Decker & Gold, n. sp.
Pl. 50, figs. G1,2

The trivial name is given to this species because the bushy upright part is similar to a forsythia bush, rising at a high angle from a basal stipe. The basal stipe has a length of 18 mm. with two branches at its distal end. The bush part has a height 14 mm. and a width of 8 mm. The basal stipe has a width of .75 mm. and the upright branches, .5 mm. Thecae occur 12 in 10 mm., and in side view they extend beyond the margin of the stipes about $\frac{1}{4}$ their length. Figure G2 (×19) shows theca to the left of *t*, a gonothecae to the right of the two *gs*, and nemathothecae on the surface of both stipes on both sides of *n*.

Type.—The form described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus Callograptus Hall, 1863
Callograptus cooperi Decker & Gold, n. sp.
Pl. 51, figs. A1,2; B1,2

This new species, described above from the lower zone, is also represented by a colony found in the upper zone.

This fan-shaped colony is 20 mm. high and 16 mm. wide. Stipes branch at angles of 8 to 12 degrees, and the bifurcation intervals are 2 to 3 mm. in the lower part and 5 mm. in the upper part. Thecae occur 16 in 10 mm. Figure A2 (×26) shows thecae at the two *t*'s, the calcified end of a polyp protruding from thecal aperture at *p*, and nematothecae on stipe to the right (*n*, *n*).

A second colony of *C. cooperi* (figs. B1,2) is a little more compact. It is 15 mm. high and 11 mm. wide. Stipes occur 16 to 20 in the space of 10 mm. They are .4 to .5 mm. wide and bifurcate at intervals of 2 to 4 mm. Thecae occur 16 in 10 mm. Figure B2 (×32) shows theca (*t*) with nematothecae (*n*) around its aperture, the end of a calcified bithecal polyp (*p*) protruding from a bithecal aperture at *b*, with nematothecae below *n*.

Remarks.—These two colonies of *C. cooperi* in the upper zone are smaller and less regular than the one in the lower zone.

Types.—These two forms are paratypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Callograptus multibifurcatus
Decker & Gold, n. sp.
Pl. 51, figs. C1,2

The trivial name is given to this species because it branches at much shorter intervals than is common in other forms under

this genus. It is 21 mm. high and 6 mm. wide. It has 5 stipes in the space of 5 mm. which are .5 to .7 mm. wide. Thecae occur 16 to 20 in 10 mm. Figure C2 (×19) shows thecae to the right of *t*, a bitheca to the right of *b*, and hive-shaped gonotheca above *g*.

Remarks.—This species has the general shape of *C. semisymmetricus* in the lower zone, but has wider more openly spaced stipes, and it branches at shorter intervals.

Type.—The form described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus CALLODENDROGRAPTUS Decker, 1945
CALLODENDROGRAPTUS SELLARDSI Decker
Pl. 51, figs. E1,2,3

Callodendrograptus sellardsi Decker, 1945, p. 30, pl. 1, fig. 4; pl. 4, fig. 5; pl. 6, figs. 3,5–8; pl. 8, figs. 1,5; pl. 9, figs. 3,3a,10.

The colony shown in E1 is 31 mm. high and 6 mm. wide. Magnified (×2) in E2, it is much clearer, showing a gonotheca to the right of *g* in the lower part, and to the left of *g* in the upper part. The angle of braching is generally 12 to 20°. The main stipe is 1 mm. wide and the branches .5 to .75 mm. wide. Thecae are small and closely set, 20 to 25 in 10 mm., bithecae are long and slender, and gonothecae are large hive- or barrel-shaped (*g*), and nematothecae extend above the surface of the stipes as at *n*.

Remarks.—This form is much like those first found and described from the Upper Cambrian Wilberns formation near Mason, Texas. This species has also been found in Tennessee and is referred to in part II below (see pl. 57, figs. E1, F1–3).

Type.—The form described above is designated an ideotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLODENDROGRAPTUS SELLARDSI var. EXPANSUS Decker
Pl. 51, figs. F1,2,3

Callodendrograptus sellardsi expansus Decker, 1945, p. 30, pl. 4, figs. 4,6; pl. 7, fig. 8; pl. 8, figs. 2–4.

This is a rather dim, poorly preserved colony with widespreading branches characteristic of this variety. The colony shown in F1 is 15 mm. high and 13.5 mm. wide. Branching is at angles of 54 to 80°. Figure F2 is quite dim, but a gonotheca shows to the right of *g* and thecae extend above the margin of the branch at *t*. Figure F3 (×20) shows bitheca at *b*, theca at *t*, gonotheca to left of *g*, calcified bithecal polyps to the right of *p*, and nematothecae extending slightly beyond the surface of the stipe at *n*.

Remarks.—This variety was named and described from the Upper Cambrian Wilberns formation near Mason, Texas, by the writer (1945, p. 30). It has also been found in Tennessee and is referred to in part II below (see also pl. 58, figs. A1–3, B1–3).

Type.—The form described above is designated an ideotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus ACANTHOGRAPTUS Spencer, 1878
ACANTHOGRAPTUS BROWNI Decker & Gold, n. sp.
Pl. 51, figs. D1,2,3

The trivial name of this species is given in honor of William R. Brown, chemist for the Viriginia Geological Survey, because he discovered the upper of the two Virginia Cambrian graptolite zones. This brushy colony is 25 mm. high and 10 mm. wide. Figure D2 (×2) shows some of the elongate tubular thecae extending above the surface of the main stipe. Figure D3 (×36) shows the very broad stipes with bithecae to the right of *b*, nematothecae hear *n*, and a large calcified polyp above *p*.

Remarks.—The elongate thecae on this form of 2 to 4 mm. are similar to those shown by Ruedemann (1947, pl. 25, figs. 4,8).

Type.—The form described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

OTHER GRAPTOLITES

On the slab from which the writer (pl. 50, figs. B1,2) has illustrated *Dendrograptus flabellites* Ruedemann, parts of a dendroid colony may be seen with meshes having the shape of those characteristic of *Palaeodictyota*.

With reference to *Dictyonema*, only a few small fragments of colonies were found in

the lower graptolite zone, but camera lucida drawings were made of parts of two colonies in the upper zone. Part of one colony is 11 mm. high and 11 mm. wide with oblong meshes and both thecae and gonothecae present. The other colony has a broad basal stipe which branches out in three-like form. Meshes are irregular, a few being elongate and narrow. The colony is 22 mm. high and 22.5 mm. wide at the top with both thecae and gonothecae showing.

SUMMARY

Of the genera and 18 species of Upper Cambrian graptolites occurring in Virginia, 9 species are new. Of the 10 species in the lower zone only 4 species reappear in the upper zone.

The study of these early graptolites by means of higher magnifications has revealed the presence not only of the commonly known thecae and bithecae, but also two new not commonly recognized structures, gonothecae and nematothecae. Gonothecae with bithecae establishes bisexual reproduction similar to that in *Hydrozoa*, and nematothecae are assumed to have been similar in function to nematocysts in Coelenterata. These new structures would seem to place graptolites as a special class, *Graptolithina*, under the Coelenterata. Birger Bohlen (1950, p. 113) has suggested this classification and in a personal letter says: "It is absolutely impossible that graptolites can be related to *Rhabdopleura* on the evidence produced by Kozlowski" (1948, p. 1–235.)

PART II: UPPER CAMBRIAN GRAPTOLITES FROM TECOY QUARRY, 7.5 MILES WEST OF KNOXVILLE, TENNESSEE

ACKNOWLEDGMENTS

In the collection and study of the Upper Cambrian graptolites of Tennessee the senior writer gratefully acknowledges the assistance of the following: Walter W. Pond, State Geologist of Tennessee, arranged for transportation and for the assistance of the late Kendall E. Born. Then Mr. H. B. Burwell, Mr. Pond's successor as State Geologist, continued to support the graptolite project by appointing his assistant geologist, H. C. Milhous, to help collect not only the Upper Cambrian graptolites, but also those from the Athens shale which the writer had been asked to study. Then for two seasons Don Kelso, a geology student, assisted with the collecting in a very efficient manner. Also, the University of Oklahoma Research Committee through its chairman, A. O. Weese, paid for some field expenses and photographs by the University Photographic Service, and continued to supply needed photographic materials.

On retiring from teaching at 82, the writer is greatly indebted to V. E. Monnett and Carl Branson for arranging for a five-year Decker Fellowship, and an interested alumnus for supplying $750.00 per year for a graduate assistant. Also it is noted that William Gold is responsible for practically all of the photographic enlargments, as substitutes were made for many of the earlier photographs, and as a result, Mr. Gold is recognized as junior author.

INTRODUCTION

The foundations for the geology of Tennessee were laid by James M. Safford, State Geologist, who, after studying the geology of all parts of the state, published his memorable volume on the geology of Tennessee, 1869. In it (p. 203) he divided the Knox group of Knox County into four members of dolomite, limestone, shale, and chert totaling a thickness of 3364 feet.

Later more detailed reports were published on the geology of northeastern Tennessee in the form of U. S. Geological Survey atlas folios. The Morristown Folio 27 by Arthur Keith (1895, p. 2) describes the Nolichucky shale in which the Upper Cambrian graptolites of Virginia and Tennessee occur, and in the columnar section has a thickness of 400–750 feet. This area is of interest because two Upper Cambrian graptolites were sent to Ruedemann (1933, p. 317,320) for description from 1.5 miles southeast of Morristown, *Dendrograptus edwardsi major* Ruedemann and *Callograptus antiquus* Ruedemann, but he credits them to the Elbrook formation from northwest Georgia instead of to the Nolichucky shale.

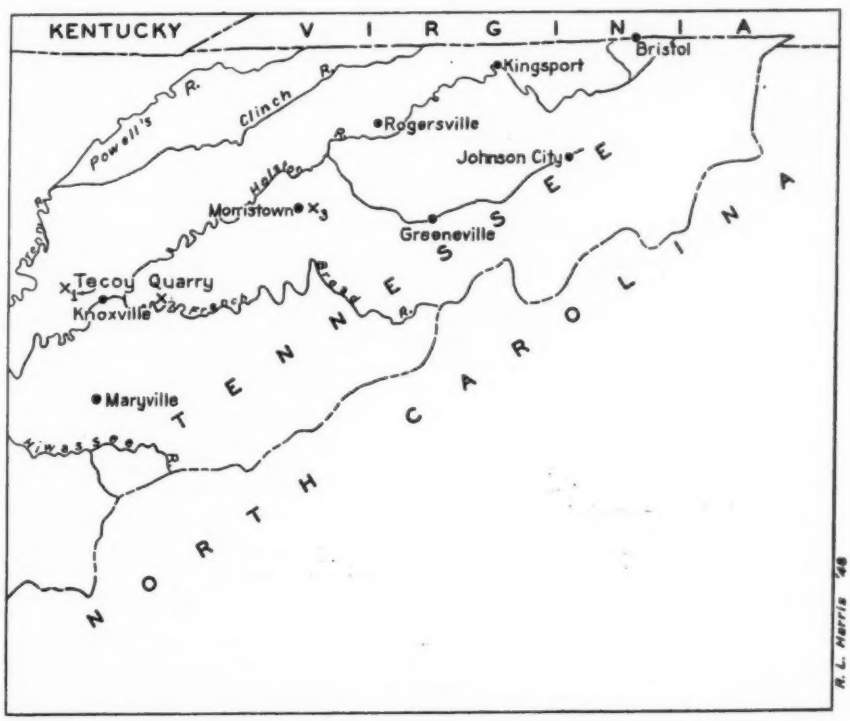
The Greeneville Folio 118, on the area east of Morristown, also by Keith (1905, p. 4,5), is of interest because the Nolichucky shale was named and described from its excellent exposure along the Nolichucky River, and it is significant in that the Upper Cambrian graptolites near Gratton, Virginia, and at Tecoy quarry west of Knoxville, Tennessee, occur in the Nolichucky shale.

Also, Ruedemann (1933, p. 325) described *Haplograptus vermiformis* Ruedemann from a locality 10 miles east of Knoxville, but after careful search in that region, Kendall Born and the writer could find no graptolite horizon exposed, and all recent collecting of the graptolites has been limited to Tecoy quarry (see text-fig. 2).

Tecoy quarry, which supplied building stone and road metal for the Knoxville region, has been abandoned for a number of years. It is at the south end of a long ridge which has its steepest slope toward the west. The quarry pit, which is filled with water, has a north-south length of 350 feet and a width of 250 feet with practically vertical walls rising from the water on the north, east, and southeast sides to a height at the east end of about 150 feet at the highest point. The quarry is opened toward the west with the loading level along the west edge.

It is difficult to tell where the Nolichucky shale starts in the quarry and it is impossible to say how much of it has been eroded from the crest of the ridge, but the graptolite zone is at the top of the vertical wall along the south edge. Fortunately for collectors, the shaly graptolite phase of the limestone was not good for road metal, so great slabs of it were left strewn over the south slope of the quarry, and in irregular piles on the loading zone level. Some of the finest colonies were secured from these rejected slabs.

The beautifully preserved collection includes 6 genera, 28 species, and 5 varieties of which 22 species are new.



TEXT-FIG. 2—Outline map of northeastern Tennessee, showing Tecoy quarry 7.5 miles west-northwest of Knoxville, Tennessee. Scale: One inch = 33.1 miles.

SYSTEMATIC DESCRIPTIONS

Animal Kingdom
Sub-kingdom INVERTEBRATA
Phylum COELENTERATA
Special Class GRAPTOLITHINA Bronn, 1846, emend. Lapworth, 1875
Order DENDROIDEA Nicholson, 1872
Family DENDROGRAPTIDAE Roemer (in Frech), 1897
Genus DENDROGRAPTUS Hall, 1858

DENDROGRAPTUS BRIDGEI Decker & Gold, n. sp.
Pl. 52, figs. A1,2

The trivial name of this species is given in honor of the late Josiah Bridge of the U. S. Geological Survey who collected some graptolites from the Tecoy quarry in 1938 and who was very much interested in the paleontology and stratigraphy of that region. The colony representing this new species is fan-shaped with both height and width of 25 mm. The bifurcation angles vary from 12 to 15° and the intervals of bifurcation are 2 to 3 mm. in the lower part and 4 to 5 mm. in the upper part. The stipes are narrow, being .3 to .5 mm. wide. Thecae occur 9–12 in 10 mm. with slight overlap, and locally sharp apertural edges extend a little beyond the margins of the stipes. A few slender bithecae show along the sides of the stipes, hive-shaped gonothecae occur at the bifurcation of the branches, and the ends of nematothecae are preserved on the edges of the apertures, and at places in transverse rows across the stipes. A theca shows (pl. 52, fig. A2) at *t*, the slender end of a bitheca to the left of *b*, and nematothecae on the surface of the stipe near *n*, and the calcified end of a polyp with nematocysts protrudes from the aperture of a theca at *p*.

Remarks.—This species differs in form from all other Cambrian species of *Dendrograptus*.

Type.—The specimen described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS BRILLHARTI Decker & Gold, n. sp.
Pl. 52, figs. B1,2

The trivial name of this new species is

EXPLANATION OF PLATE 51

Callograptus, *Acanthograptus*, and *Callodendrograptus* from Virginia (lower zone)

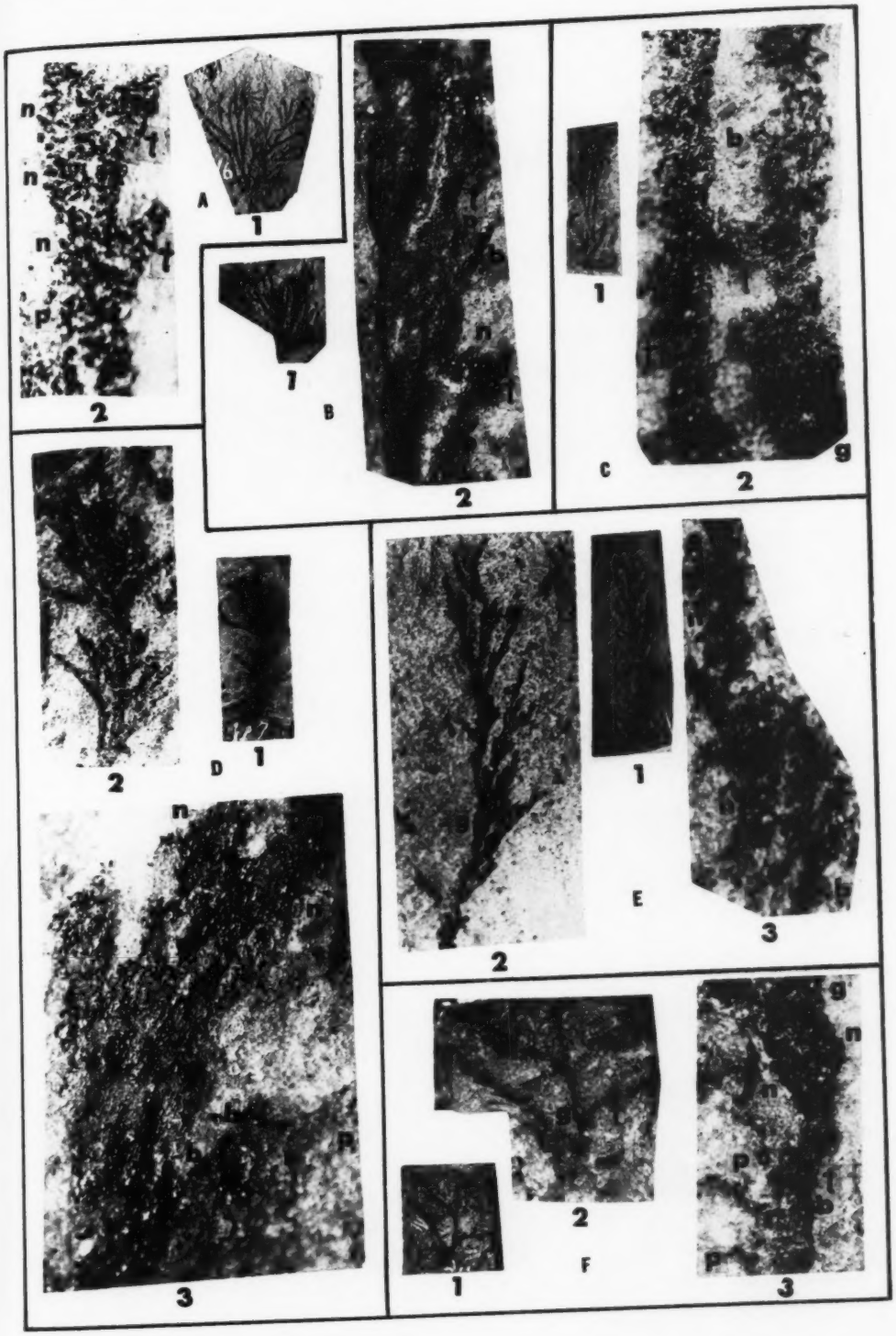
FIGS. *A,B*—*Callograptus cooperi* Decker & Gold, n. sp. *A,B*, paratypes. *A1*, part of a colony (×1). *A2*, part of a stipe (×26) showing thecae (*t*), nematothecae at *n*, and end of calcified polyp (*p*) protruding out of thecal aperture with nematocysts around its aperture. *B1*, colony (×1). *B2*, part of a stipe enlarged (×26) showing thecae (*t*), elongate slender bithecae (*b*), and nematothecae (*n*) around the apertures of bottom and top thecae.

C—*Callograptus multibifurcatus* Decker & Gold, n. sp. *C*, holotype. *C1*, part of colony (×1). *C2*, part of two stipes (×19) showing thecae along lower part of left stipe (*t*), and above (*t*) between the stipes on dissepiment, bitheca to right of *b*, and gonotheca, lower right above *g*.

D—*Acathograptus browni* Decker & Gold, n. sp. *D*, holotype. *D1*, colony (×1). *D2*, colony (×2) showing some elongate thecae standing almost at right angles to surface. In the upper half of the colony round, white apertures help to identify the elongate thecae, but some thecae show also on the lower half. *D3*, part of a broad flat branching stipe (×17) showing great width characteristic of the genus; a light colored calcified polyp above *p* showing aperture with nematothecae preserved on its side, end of a bitheca at upper *b* and right part of another one to the right of lower *b* partly hidden by a big dark calcified polyp with nemathothecae on its sides, and nematothecae are scattered over the stipe and show well at right of *n* at the top.

E—*Callodendrograptus sellardsi* Decker. *E*, ideotype. *E1*, colony (×1). *E2*, colony (×2), gonotheca at *g*. *E3*, parts of stipes (×17) showing thecae (*t*) with light apertures, end of bitheca to left of *b*, and ends of nematothecae (*n*) projecting beyond the margins of the stipe.

F—*Callodendrograptus sellardsi* var. *expansus* Decker. *F*, ideotype. *F1*, colony (×1). *F2*, colony (×2) showing gonotheca to right of *g*, and thecae extending beyond margin of two stipes. *F3*, part of a stipe (×20) showing theca to the left of *t*, upright bitheca to left of *b*, gonotheca to left of *g*, nematothecae extending slightly beyond the surface to right and left of *n*, and ends of two calcified polyps (*p*), (*p*).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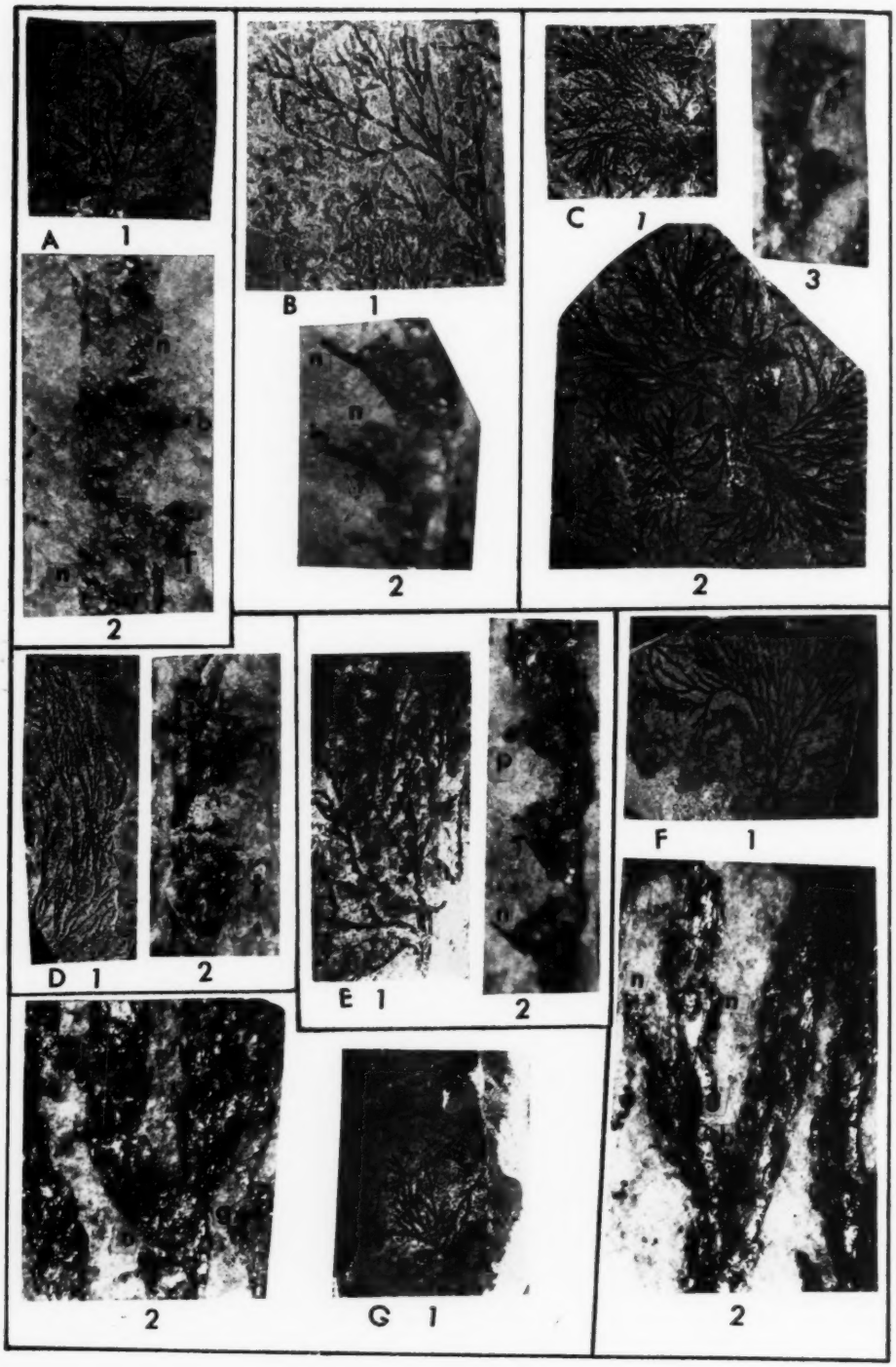
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given in honor of an alumnus, Norman W. Brillhart, who supports the fellowship making possible the continuation of research on graptolites at the University of Oklahoma. The beautiful tree-like colony representing this species is 37 mm. high and 33 mm. wide with the main stipe bending distinctly to the left. If straightened, the curving main stipe has a height of 46 mm. and the colony in that position a width of 3 mm. The major central stipe has width of 1 to 1.5 mm. The branches vary in width from .5 to 1 mm. The large branches rebranch to form brush-like ends, the bifurcation angle varies from 10 to 35°. Thecae occur 10 to 12 in 10 mm. with little if any overlap and in some parts the apertural ends of thecae extend above the surface of the stipe (pl. 52, fig. B2). Most of the periderm has been exfoliated, and pyrite flat-irons have been deposited along them. Thecae occur 10 to 12 in 10 mm. Bithecae show on some, the stipes parallel to the thecae, and some gonothecae have apertures open at the point of bifurcation. Nematothecae have been preserved around the apertures and on the stipes (fig. B2 at *n*).

Remarks.—Other than *Dendrograptus hicorius*, this is the most tree-like graptolite known, and it differs from the former in having long, straight branches instead of the shorter curved ones of *hicorius*.

Type.—The specimen described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus edwardsi major Ruedemann

Pl. 52, figs. C1,2,3; D1, 2

Dendrograptus edwardsi var. *major* Ruedemann, 1933, p. 317, pl. 49, figs. 1,2,5,7.—Decker, 1936, p. 304.

Dendrograptus edwardsi var. *major* Ruedemann, 1947, p. 211, pl. 19, figs. 16–20.

This large variety was described by Ruedemann (1933, p. 217, pl. 49, figs. 1,2,5,7) from a large broken colony from the Tecoy quarry. A similar colony collected more recently from that quarry is shown in figures C1 (×1), C2 (×2), and C3 (×17) in which figure C2 is the reverse of figure C1. This later colony has a height of 28 mm. and a width of 23 mm. This must be a young colony, since the one illustrated by Ruedemann is more than twice as large. The enlargement of a stipe (C3, ×17) shows theca with characteristic sharp apertural margin with nematothecae on the theca (*t*) and on stipe near *n*.

A part of a more mature colony of this variety is shown in figure D1 (×1) and an enlargement (D2, ×17) showing theca to the left of *t*, bitheca below *b* and nematothecae to the left of *n*. The stipes occur in

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Explanation of Plate 52

Dendrograptus from Tecoy quarry, Tennessee

Fig. *A*—*Dendrograptus bridgei* Decker & Gold, n. sp. *A*, holotype. *A1*, colony (×1). *A2*, part of a stipe (×17) showing theca above *t*, bitheca at *b*, nematothecae near *n*, end of calcified polyp at *p*.

B—*Dendrograptus brillharti* Decker & Gold, n. sp. *B*, holotype. *B1*, colony (×1). *B2*, small part of stipe (×26) showing theca at *t*, nematothecae at left near *n*, and around thecal apertures at *n*.

C,D—*Dendrograptus edwardsi major* Ruedemann. *C,D*, topotypes. *C1*, colony (×1). *C2*, colony (×2). *C3*, part of a stipe (×17), showing theca above *t*, nematothecae to left of *n*. *D1*, colony (×1). *D2*, part of a stipe (×17) showing theca to left of *t*, nematotheca above *n*, and bitheca to left of *b*.

E—*Dendrograptus* sp. cf. *D. edwardsi* Ruedemann. *E*, ideotype. *E1*, colony (×2) showing thecae. *E2*, part of a stipe (×17) showing theca at *t*, nematothecae around aperture, and end of calcified polyp (*p*).

F—*Dendrograptus grapei* Decker & Gold, n. sp. *F*, holotype. *F1*, colony (×1). *F2*, part of 3 stipes (×17) showing bitheca to left of *b*, gonotheca to left of *g*, and nematotheca around thecal aperture and on stipe (*n*).

G—*Dendrograptus flabellites spreadatus* Decker & Gold, n. var. *G*, cotype. *G1*, colony (×1). *G2*, part of 3 stipes (×26) showing gonotheca to left of *g* and nematothecae scattered over stipes near *n*.

an open curve each .5 mm. wide. Thecae occur 9–11 in 10 mm.; the width of colony is 11 mm.; much of the colony is covered in the limestone. Gonothecae show at birfurcation of stipes and nematothecae on margin of thecal apertures.

Remarks.—The size and shape of the stipes are most like the one illustrated earlier by Ruedemann (1933, pl. 49, fig. 1) from this locality.

Types.—The specimens of this variety illustrated here are topotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS sp. cf. D. EDWARDSI Ruedemann
Pl. 52, figs. E1,2

Dendrograptus edwardsi Ruedemann, 1933, p. 316, pl. 47, figs. 2,408; pl. 49, figs. 3,4,6.—Decker, 1936, p. 304.
Dendrograptus edwardsi Ruedemann, 1947, p. 210, pl. 19, figs. 5–15.

This species was described by Ruedemann from fragments of stipes, the longest of which is less than half an inch, and a fragment less than half an inch long was designated the holotype.

The part of a colony illustrated in figures E1, (×2) and E2 (×17) has a height of 22 mm. and a width of 11 mm. In figure E1 the sharp ends of the thecae show well. In the enlargement (fig. E2) thecae show at *t*, nematotheca at *n*, and end of calcified polyp at *p*. Gonothecae show at point of bifurcation of stipes, and some nematothecae are preserved around the thecal apertures. Thecae occur 12–14 in 10 mm., which averages about 3 more than is typical of *D. edwardsi*.

Remarks.—Such a difference is to be expected when one realizes that the Tennessee material is in a very much earlier horizon than the forms from the type localities in Wisconsin and Minnesota.

Type.—The specimen described above is designated an ideotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS GRAPEI Decker & Gold, n. sp.
Pl. 52, figs. F1,2

The trivial name given this species is chosen because the colony spreads like a grape vine. The upper part of the colony has been broken off. The part remaining is 25 mm. high and 32 mm. wide near the top. The bifurcation angle is small, 5 to 8°, and the bifurcation interval short, generally 2 to 3 mm., thus making a very compact colony, yet having the stipes clearly distinguishable. Stipes have a width of .5 to .7 mm. The bifurcation interval in the upper right is so short on two of the stipes, it looks as though three branches start at nearly the same level. Yet at the numerous bifurcations a clear hive-shaped gonotheca shows at nearly every bifurcation. The periderm is exfoliated from much of the colony, yet where it occurs, especially in the upper part, the ends of nematothecae protrude beyond the margins of the stipe. A few bithecae show parallel to the thecae on some wider stipes.

In the lower narrow part, some of the stipes bend around and coalesce to surround two small fenestrules, and a little higher two stipes coalesce to surround an elongate fenestrule as though in an attempt to start a *Dictyonema*. But there is no further evidence of such an attempt. Thecae are short and occur 15 in the space of 10 mm.

Remarks.—This new species of *Dendrograptus* has a distinctive shape all its own which no other colony closely approaches.

Type.—The specimen described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS FLABELLITES var. SPREADATUS Decker & Gold, n. var.
Pl. 52, figs. G1,2

The trivial name for this new early variety is given because the stipes are spread leaving spaces between, whereas the later species has the broad stipes crowded closely together. The colony is young with a height of only 17 mm. and a width of 13 mm. The stipes have a width of .5 mm. and the thecae are short occurring 18 in 10 mm. or 2 more than in the species *flabellites*. The short relatively broad thecae are shown on plate 52, figure G2, as well as the spaces between the stipes. Hive-shaped gonothecae occur at the bifurcations as shown

at *g*, and nematothecae occur along the stipes as shown near *n*.

A second colony of this new variety is shown on plate 53, in figures B1 and B2. In figure B1 (×2) the relatively broad stipes are shown more closely together than in the previous colony. This colony is 27 mm. high and 18 mm. wide. The enlargement (B2, ×17) shows the relatively short broad thecae with tiny bright apertures, gonothecae to the left of *g*, and nematothecae (*n*) along on the stipes. Thecae are very short, only .5 mm. long; there are 20 in 10 mm., or four more than in *D. flabellites*.

Remarks.—The stipes in this variety approach the closer parallel condition characteristic of *D. flabellites*.

Types.—These two colonies are cotypes for the new variety.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus elboi Decker & Gold, n. sp.
Pl. 53, figs. A1,2

The trivial name for this new species is given because of the exceptional way that the stipes bend like elbows. The colony shown in figures A1 (×1) and A2 (×17) is 38 mm. high and 22 mm. wide. The main stipe has a width of 1 mm. and the branches .7 mm. Thecae occur 16–18 in 10 mm. A number of gonothecae occur at *g* and a bitheca at *b*, with nematothecae on the stipes near *n*. Two gonothecae are shown to the left of *g* in figure A2.

Remarks.—No other species of *Dendrograptus* is known in which the stipes bend in such an elbow-like manner.

Type.—This colony is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus hallianus monemakeri Ruedemann
Pl. 53, figs. C1,2,3, D1,2

Dendrograptus hallianus monemakeri Ruedemann, 1947, p. 212, pl. 18, figs. 14,15.

Two colonies have been chosen to represent this variety. The first one (pl. 53, figs. C1, ×2, and 3, ×17) is more nearly the shape of Ruedemann's (1947, pl. 18, fig. 2) *D. hallianus*, though a little shorter and broader than his figure. Thecae extend beyond the margin of the stipe and show above *t* at lower left. It is 20 mm. high and 19 mm. wide. The bifurcation intervals are 1–2 mm. in the lower part and 2 to 4 mm. in the upper part. Stipes are very narrow, main stipe .6 mm. and branches .3 mm. wide. Thecae occur 20 in 10 mm. or they are .5 mm. long. On the wider parts of stipes, bithecae show parallel to the thecae, gonothecae occur at the bifurcations, and where periderm is well preserved, nematothecal ends protrude beyond the margins of the stipes. Figures C2 and C3 (×17) show calcified polyps with nematocysts protruding from the apertures of the thecae at *p*, bithecae at *b*, and nematothecae at *n*.

The second colony (pl. 53, figs. D1, ×1, D2, ×17) is bent over in a rather exceptional way, and in general form it is similar to Ruedemann's illustration of *D. hallianus* (1947, pl. 18, fig. 1). If straightened up the colony would be 42 mm. high and 8 mm. wide. Bithecae show on some stipes, gonothecae occur at the bifurcations, and nematothecae are abundant on the surface of the stipes. Thecae are .5 mm. long, or occur 20 in 10 mm.

Remarks.—These two colonies come from the same Tecoy quarry, Knox Co., Tennessee as the specimen illustrated by Ruedemann (1947, pl. 18, fig. 14).

Types.—As the two colonies described above were collected from the same horizon and locality as the holotype of the variety, they are designated topotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus hicorius Decker & Gold, n. sp.
Pl. 54, figs. A1,2,3

This species has been described above from Virginia. A colony from Tennessee is 37 mm. high and 26 mm. wide. The branching is quite open with considerable distances between the stipes, and the branching interval is from 1 to 3 mm. Most of the branches curve, and at the distal ends bifurcate at angles of 20 to 25°. The main stipe is 1 mm. wide and the branches .4 to .6 mm. wide. Thecae occur 12–14 in 10 mm. Bithecae show on some of the stipes parallel to the thecae. Gonothecae occur below

the point of branching, and nematothecae protrude above the surface of the stipes.

Remarks.—This new species has a shape very similar to Ruedemann's (1947, pl. 18, fig. 14) *D. hallianus moneymakeri* from the same quarry. However, it is more evenly and more openly branched and has 6 to 8 less thecae in 10 mm., so the thecae are much larger and longer.

Type.—The specimen is designated a paratype, as the species was described above from the upper zone at Gratton, Virginia.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus japonicus Decker & Gold, n. sp.
Pl. 54, figs. B1,2,3

The trivial name of this new species is given because it branches in a manner similar to that of the japonica bush. The colony is 31 mm. high and 41 mm. wide. The branching is extremely open with broad spaces between the stipes. The angle of branching varies from 20 to 40° as branches of the second, third and fourth orders are developed. The stipes are narrow, .3 to .5 mm. wide. Thecae occur 15 in 10 mm. and bithecae can be seen parallel to them on some of the stipes. A few hive-shaped gonothecae occur at the bifurcations, and rather large barrel-shaped ones stand out on the margins of the stipes. Locally, some nematothecae are preserved. Large parts of the colony are pyritized.

In figure B1 (×4), the sharp points of thecae show beyond the margin of the stipe at *t*. In figure B2 a theca shows at *t*, nematotheca at *n*, and a calcified polyp above *p*, and in figure B3 a bitheca below *b*, a gonotheca to the right of *g*, and nematothecae near *n*.

Remarks.—If one considers the colony as a whole, no other *Dendrograptus* has a widespread branching with large areas between the stipes.

Type.—The specimen described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus kelsoi Decker & Gold, n. sp.
Pl. 54, figs. C1,2,3,4

The trivial name of this species is given in honor of Don Kelso, an efficient field assistant and skilled driver. The colony is large, widespreading, with exceedingly narrow stipes. The colony is 38 mm. high and 53 mm. wide in upper part where it spreads like a mushroom (pl. 54, fig. C1). The stipes near the base are .5 mm. wide, elsewhere they are .2 mm. wide. Thecae occur 12–14 in 10 mm., and in side view they extend more than half their width beyond the margins of the stipes (see figs. C2,3). In figure C4 a theca is shown at *t* with nematothecae around its aperture and on its side. Nematothecae show also on the stipe at *n* lower right. The aperture of a bitheca occurs to the right of *b*, and a calcified polyp with nematocysts above *p*. Gonothecae show at a number of the bifurcations, the intervals of which are very long, especially in the middle and upper parts of the colony.

Remarks.—This species is characterized by very narrow stipes with protruding thecae as shown in figure C2 (×2) and especially in figure C3 (×12).

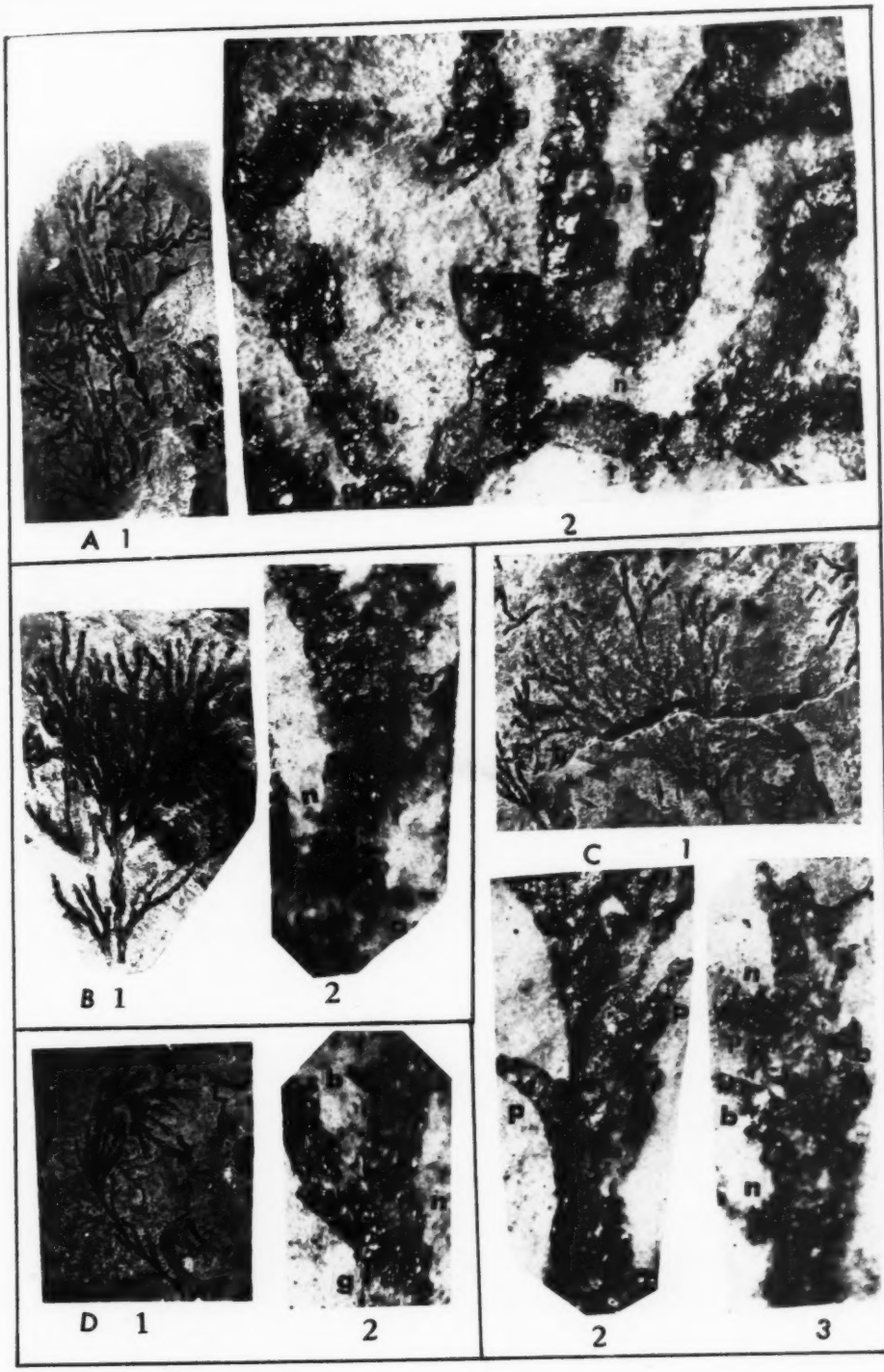
Explanation of Plate 53

Dendrograptus from Tecoy quarry, Tennessee

Fig. *A*—*Dendrograptus elboi* Decker & Gold, n. sp. *A*, holotype. *A1*, colony (×1). *A2*, part of colony (×26) showing elbow-like turns, two gonothecae at lower left *g* and left of *g* upper middle, bitheca at *b*, and nematothecae near *n*.

B—*Dendrograptus flabellites spreadatus* Decker & Gold, n. var. *B*, cotype. *B1*, colony (×1). *B2*, part of a stipe (×26) showing gonotheca to left of *g* at bottom and higher up, nematothecae on stipe (*n*).

C,D—*Dendrograptus hallianus moneymakeri* Ruedemann. *C,D*, topotypes. *C1*, colony (×2). *C2*, part of stipe (×26) showing calcified polyps at *p* and nematothecae along stipe. *C3*, part of stipe (×26) showing calcified polyp (*p*), bitheca (*b*), and nematothecae at *n*. *D1*, bent colony (×1). *D2*, part of branching stipe (×17) showing gonotheca to right of *g*, bitheca at *b*, nematothecae on stipe (*n*).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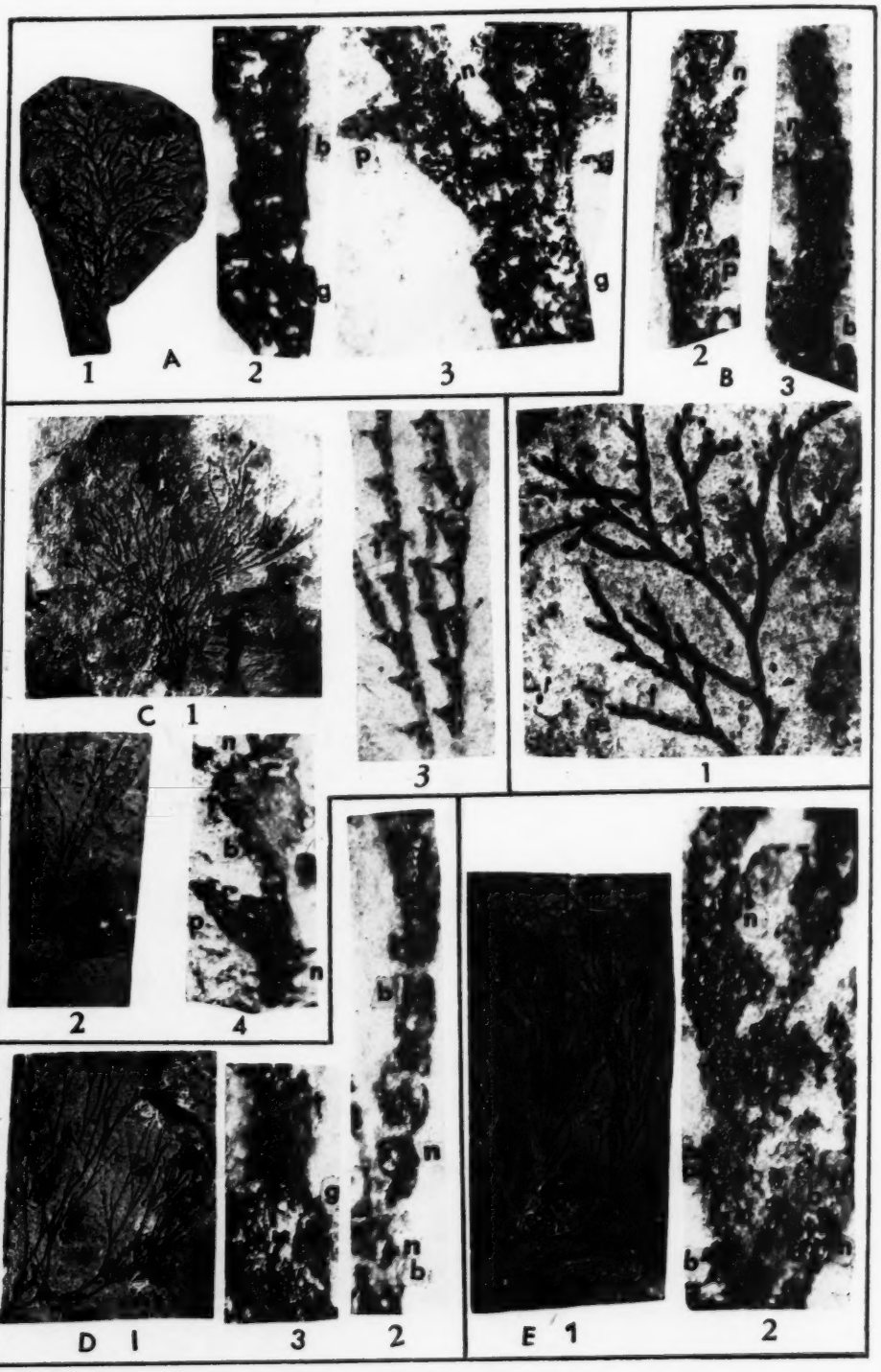
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Type.—This colony is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS MISERI Decker & Gold, n. sp.
Pl. 54, figs. E1,2

The trivial name for this species is given in honor of Hugh D. Miser, of the U. S. Geological Survey, who gave information about the stratigraphy of the Tecoy area and detailed descriptions of localities in northeastern Tennessee from which Cambrian graptolites had been collected earlier. The basal part of this colony is wanting, on another slab the basal part of the colony branches out and divides into two or three similar parts, each of which looks like a distinct colony. The specimen illustrated has 10 to 15 mm. broken off from the base. The height of the part of the colony preserved here is 41 mm. and the width is 25 mm. The stipes are elongate, bend some and are very close together so they frequently overlap in parts of the colony. The periderm has been brittle so that the stipes are broken into short pieces, then with some abrasion on the surface and exfoliation, much of the colony looks like the condition seen in figure E2 (×17). Quite a number of large hive-shaped gonothecae are preserved, some bithecae (*b*) show and locally nematothecae at *n* and a calcified bithecal polyp above *p*. There is a peculiar condition among the stipes, some of them are very broad, twice as wide as others.

Remarks.—The, elongate, slender parallel stipes in this species are somewhat like those in Ruedemann's (1947, pl. 20, fig. 12) *Dendrograptus fruiticosis;* however, it does not have the broad curving main stem of the latter. In a way the broad stipes mentioned above are more like those in his (1947, pl. 20, fig. 18) specimen.

Type.—The above specimen is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

DENDROGRAPTUS OPENATUS Decker & Gold, n. sp.
Pl. 55, figs. A1,2,3

The trivial name *openatus* is given this species; even though branches of the fourth order are developed, there still are large interspaces between them, giving the colony a very open appearance. The colony is 37 mm. high and 20 mm. wide. The interval of branching is 2–4 mm. and the angle of branching 20 to 30°. Stipes are from .4 to .7 mm. wide. Thecae occur 12 in 10 mm. A few bithecae may be seen parallel to the thecae, and gonothecae are preserved at a number of the bifurcations, and tiny nematothecae occur around the apertures of some of the thecae. The colony is shown in figures A1 (×1) and A2 and 3 (×17). In figure A2 there is a gonotheca above *g*, a calcified polyp to the left of *p*, a bitheca to the right

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EXPLANATION OF PLATE 54

Dendrograptus and *Callograptus* from Tecoy quarry, Tennessee

FIG. *A*—*Dendrograptus hicorius* Decker & Gold, n. sp. *A*, paratype. *A1*, colony (×1). *A2*, part of a stipe (×26) showing gonotheca at *g* and bitheca at *b*. *A3*, part of branching stipe (×33) showing gonotheca to left of *g*, calcified polyp at *p*, bithecal polyp below *b*, nematothecae over stipe as at *n*.

B—*Dendrograptus japonicus* Decker & Gold, n. sp. *B*, holotype. *B1*, colony (×2) showing sharp thecae. *B2,3*, parts of stipe (×17) showing theca at *t*, calcified polyp (*p*), nematothecae at *n*, bitheca below *b*, gonotheca to right of *g*.

C—*Dendrograptus kelsoi* Decker & Gold, n. sp. *C*, holotype. *C1*, colony (×1). *C2*, part of colony (×2) showing thecae. *C3*, several stipes (×12) showing sharp thecal points (*t*). *C4*, part of stipe (×17) showing theca at *t*, with nematothecae around aperture (*n*), bitheca (*b*), calcified polyp with nematothecae preserved (*p*).

D—*Callograptus milhousi* Decker & Gold, n. sp. *D*, holotype. *D1*, colony (×1). *D2*, part of stipe (×17) showing bithecae (*b*), and nematothecae (*n*). *D3*, part of stipe (×26) showing large gonotheca at left of *g*.

E—*Dendrograptus miseri* Decker & Gold, n. sp. *E*, holotype. *E1*, colony (×1). *E2*, part of branching stipe (×17) showing bitheca (*b*), bithecal polyp above *p*, and nematothecae scattered over surface of stipe (*n*).

of *b*, and nematothecae on the stipe to the right of *n*. In figure A3 (×17) there is a theca above *t*, bitheca to right of *b*, and nematothecae on the theca and near *n* on the stipe.

Remarks.—This colony has more regular branching and larger interspaces than most species.

Type.—The colony of this new species is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus peculiarus Decker & Gold, n. sp.
Pl. 55, figs. B1,2

The trivial name of this new species is given because of the exceptional manner of branching chiefly on one side. The colony is 25 mm. high and 18 mm. wide, with all of the branches on the right. This condition may be due to a splitting off of the left part of the colony. The branching is at intervals of 2 to 3 mm. at an angle of about 40 degrees. Stipes are about .5 mm. wide. Thecae occur 14 in 10 mm. and they extend beyond the margins of the stipes. Much of the periderm is exfoliated. Bithecae show on one branch. In figure B2 thecae show at *t*, a gonotheca to the left of *g*, and nematothecae to the left of *n*.

Remarks.—Branches on one side only, curving somewhat but in general parallel.

Type.—The colony described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus tecoyensis Decker & Gold, n. sp.
Pl. 55, figs. C1,2

The trivial name of this species given for the Tecoy quarry from which it was collected. It is only a partial colony, as parts are broken from both sides, yet it seems sufficiently distinctive to be described as a species. In general the stipes look flat, rather wide, and rigid. The height is 20 mm. and width 10 mm. The stipes are .7 to 1 mm. wide. The interval of branching is generally 2 to 3 mm.; however, after bifurcation, one of the branches bifurcates again giving the appearance of three branches from almost the same level. The colony is shown in figures C1 (×1) and C2 (×17). Figure C1 shows two of the places where the three branches appear to come from nearly the same level. Figure C2 (ends reversed) shows the rather flat broad stipe in which it is difficult to differentiate individual thecae. A gonotheca occurs at the top to the left of *g*. Under a magnification of ×36 some of the stipes show bithecae parallel to the thecae with an occasional turning and extending its aperture beyond the margin of the stipe.

Remarks.—This species differs from others in its flat, broad, rigid stipes and in its peculiar branching.

Type.—This form described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Dendrograptus thomasi Ruedemann
Pl. 55, figs. D1,2; E1,2

Dendrograptus thomasi Ruedemann, 1933, p. 317, 318.—Decker, 1936, p. 304.
Dendrograptus thomasi Ruedemann, 1947, p. 213, 214.

This species was described earlier by Ruedemann from the Deadwood formation, Deadwood, South Dakota, and by the writer (1945, p. 26) from the Wilbern's formation near Mason, Texas. A colony has been selected from the Tecoy, Tennessee collection to represent this species (pl. 55, fig. D1, ×2; 2, ×17). In figure D1 (×2) the general characteristics of the species in a small colony with narrow stipes with relatively short slightly curved branches. The colony is 15 mm. high and 9 mm. wide. Thecae are short, occurring 16 in 10 mm. Branching intervals are 1 to 2 mm., and the stipes have a width of .4 to .5 mm. and thecae extend somewhat beyond the margin of the stipes. Bithecae occur along the sides of some of the wider stipes and gonothecae occur at several of the bifurcations. Tiny nematothecae are preserved on the surface of the stipes. In figure D2 (×1) a gonotheca is seen above the lower *g* and to the right of the upper one, and a nematotheca in stipe to left of *n*. Figure E2 (×26) shows gonothecae at left of lower and upper *g*, and nematotheca at *n*.

Remarks.—These two colonies have the narrow stipes, short branches and numerous thecae characteristic of the type form.

Types.—These two colonies are designated ideotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus ASPIDOGRAPTUS Bulman, 1934
(Genotype originally designated *Clematograptus implicatus* Hopkinson)
ASPIDOGRAPTUS INTERMEDIUS Decker & Gold, n. sp.
Pl. 55, figs. G1,2

The trivial name of this species is given because it is intermediate between Bulman's (1934, p. 71–74) *A. implicatus* and *A. minor*. The colony has a height of 23 mm. and a width of 11 mm. The main circular stipe is well developed. The radiating branches vary in length from 7 to 14 mm. and are about .3 of a mm. wide. Thecae occur 18 in 10 mm. Bithecae occur parallel to the stipes, or projecting from the margins. Figure G2 (×26) shows theca at *t*, bitheca to left of *b* on right middle and top, and nematothecae around thecal apertures at *n*.

Remarks.—It is a typical part of a colony though only part of the radiating stipes are preserved. It was described above from Virginia.

Type.—This form is designated a paratype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

ASPIDOGRAPTUS PRAEMINOR Decker & Gold, n. sp.
Pl. 55, figs. F1,2

The trivial name of this species is given because it is from a much earlier horizon than *A. minor*. It is a tiny colony (pl. 55, fig. F1, ×3) only 10 mm. high and 9 mm. wide. The typical curved stipe has only 5 radiating ones which are .3 mm. wide. Branching intervals are 1 to 2 mm. Thecae occur 18 in 10 mm. Gonotheca occur at the bifurcations. Shown by Bulman (1934, pl. 10, figs. 1–3) are parts of 3 other colonies, Shelve Church beds, Arenig—*Didymograptus extensus* zone of Arenig or *Didymograptus extensus* zone of Beekmantown. The writer (1945, p. 35, pl. 10, figs. 9–14) assembled parts of an *Aspidograptus* from the Wilberns Upper Cambrian, from near Mason, Texas. Ruedemann (1947, p. 227, figs. 10,11) has illustrated *Aspidograptus parallelus* from the Sawatch Upper Cambrian formation from Pitkin County, Colorado. This form has very straight closely spaced parallel stipes radiating from the top of a major stipe, but with no evidence of a main curved stipe. The writer (pl. 49, fig. A1) has in this paper described a large part of a colony as *A. intermedius* from the Nolichucky shale, lower zone, Upper Cambrian from Gratton, Virginia, and now has found several specimens of *A. intermedius* in the Chambersburg limestone member of the Nolichucky shale at Tecoy quarry, Knox County, Tennessee.

Remarks.—Described by Bulman from the Ordovician of England in beds equivalent to the *Didymograptus extensus* zone in the Beekmantown, this species occurs in the Upper Cambrian of Virginia, Tennessee, Texas, and Colorado.

Type.—The illustrated specimen is designated the holotype.

Repository.—Museum of of Invertebrate Paleontology, University of Oklahoma.

Genus SYRRHIPIDOGRAPTUS Poulsen, 1924
SYRRHIPIDOGRAPTUS sp. cf. S. BURKESGARDENSIS Decker & Gold, n. sp.
Pl. 56, figs. A1,2,3

The trivial name of this species was given to a form described from the Burkes Garden quadrangle of southwestern Virginia. The part of a colony illustrated in figure A1 (×2) shows only a marginal part of a colony over an area of 20 to 22 mm. with open branching at large angles, whereas typically the stipes occur nearly parallel in a fan-shaped colony. The stipes are .5 mm. wide with elongate tubular thecae standing at a high angle with the stipes, thecae being 4 or 5 times as long as wide with circular apertural openings and with nematothecae around some of the apertures and on the sides of the thecae. Thecae occur 16 in 10 mm. In figure A1 (×2) the tubular thecae project from the margins of the stipes. In figures A2 (×17) and A3 (×33) thecae show at *t*, nematothecae at *n* around thecal apertures, and a polyp calcified at *p* extending out of the thecal aperture.

Remarks.—The thecae shown here are less than half the length of some of them on the colony. The new genus and species *syrrhipidigraptus nathorsti* Poulsen (1924) came from the Ordovician of Borholm Island, and

as Poulsen did not find bithecae, he put it under *Graptoloidea*. He sent me a poorly preserved duplicate specimen on one stipe of which two bithecae are preserved, and bithecae are common on the new species from southwestern Virginia, so it is now placed under *Dendroidea*.

Type.—The form described above is designated a paratype.

Repository.—Museum of Paleontology, University of Oklahoma.

Genus CALLOGRAPTUS Hall, 1865

CALLOGRAPTUS COOPERI Decker & Gold, n. sp.

Pl. 56, figs. B1,2; C1

Specimens of this species have been described above from Virginia. The colony shown in figure B1 (×1) is relatively wider than the holotype from Virginia. The colony is 21 mm. high and 37 mm. wide. Stipes are .25 to .5 mm. wide, branching at intervals of 2 to 3 mm., at angles of 10 to 12°. Stipes are not so rigid as to prevent crossing in some parts of the colony. Thecae are tubular and nearly parallel with the stipes as a rule, but ends extend beyond margins of stipes (pl. 56, fig. B2). There nematothecae are preserved around the thecal apertures and the calcified end of a polyp extends out of the thecal aperture at *p*.

A second colony of *C. cooperi* from the Tecoy, Tennessee quarry (fig. C1, ×1) has a fan-shape more like that of the holotype from Gratton, Virginia.

Remarks.—This new species was well developed both in Virginia and Tennessee.

Type.—These are paratypes, collected from a different locality from the holotype.

Repository.—Museum of Paleontology, University of Oklahoma.

CALLOGRAPTUS LILACUS Decker & Gold, n. sp.

Pl. 56, figs. D1,2,3; E1

The trivial name of this new species is given because it branches like a lilac bush as shown in figure D1 (×2). The colony is 21 mm. high and 14 mm. wide. Stipes are .5 to .75 mm. wide. Branching intervals vary from 2 to 5 mm. at angles of 8 to 12°. Thecae occur 16 in 10 mm. Bithecae are shown on some stipes parallel to the thecae, nematothecae are preserved on some stipes, and gonothecae occur just below the points of bifurcation of stipes. A few dissepiments are present. This symmetrical colony is shown in figure D1 (×2). A part of a stipe and one theca (*t*) shows in figure D2 (×33) with bitheca at *b*, and nematothecae near *n*.

An enlargement of a paratype (fig. E1, ×26) shows theca on the left to the right of *t*, a bitheca to the left of *b*, and nematothecae on the right near *n*.

Remarks.—This new species is distinctive in form and branching from other species of *Callograptus*.

Types.—The specimen illustrated in figure D1 is designated the holotype and that in E1 the paratype.

EXPLANATION OF PLATE 55

Dendrograptus and *Aspidograptus* from Tecoy quarry, Tennessee

FIG. *A*—*Dendrograptus openatus* Decker & Gold, n. sp. *A*, holotype. *A1*, colony (×1). *A2*, part of a stipe (×17) showing a gonotheca (dark) above *g*, bitheca at *b*, nematothecae near *n*.

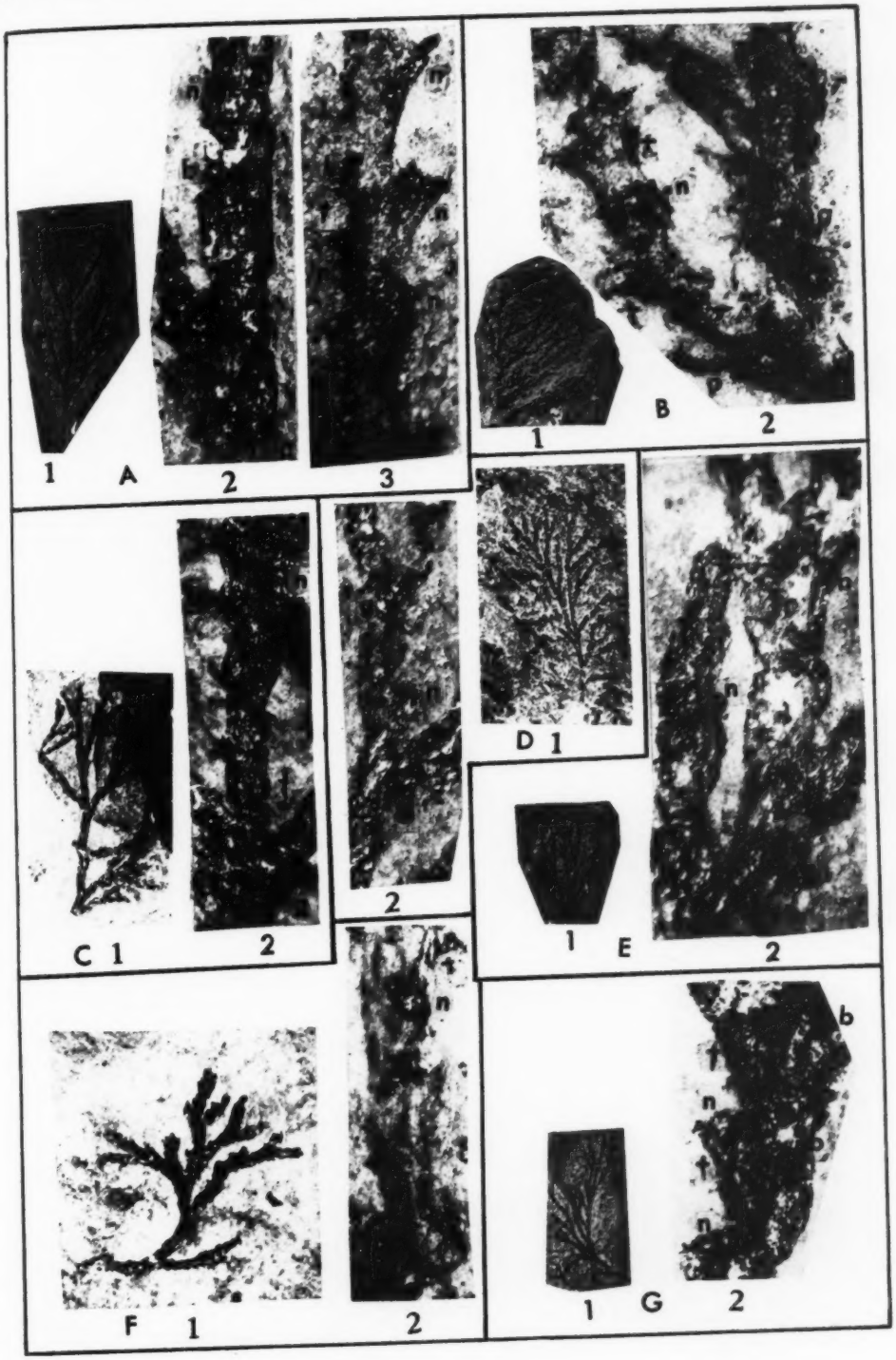
B—*Dendrograptus peculiarus* Decker & Gold, n. sp. *B*, holotype. *B1*, colony (×1). *B2*, parts of stipes (×17) showing theca at *t*, gonotheca to left of *g*, nematothecae near *n*, polyp at *p*.

C—*Dendrograptus tecoyensis* Decker & Gold, n. sp. *C*, holotype. *C1*, colony (×1). *C2*, part of a stipe (×17) showing gonotheca at *g*, theca at *t*, nematothecae at *n*.

D,E—*Dendrograptus thomasi* Ruedemann. *D,E*, ideotypes. *D1*, colony (×2) showing thecae extending beyond margins of stipes. *D2*, part of branching stipe (×17) showing gonotheca at lower right above *g* and to right of *g* higher up, and nematothecae on stipe to left of *n*. *E1*, colony (×1). *E2*, part of two stipes (×26) showing gonotheca to right of *g*, bitheca above *b*, nematothecae along stipe to left of *n*.

F—*Aspidograptus praeminor* Decker & Gold, n. sp. *F*, holotype. *F1*, colony (×3). *F2*, part of stipe (×17) showing theca above *t* with nematothecae on it and nematotheca to left above *n*.

G—*Aspidograptus intermedius* Decker & Gold, n. sp. *G*, paratype. *G1*, colony (×1). *G2*, part of a stipe (×26) shows thecae at *t*, bitheca to left of *b*, and nematothecae around thecal apertures at *n*.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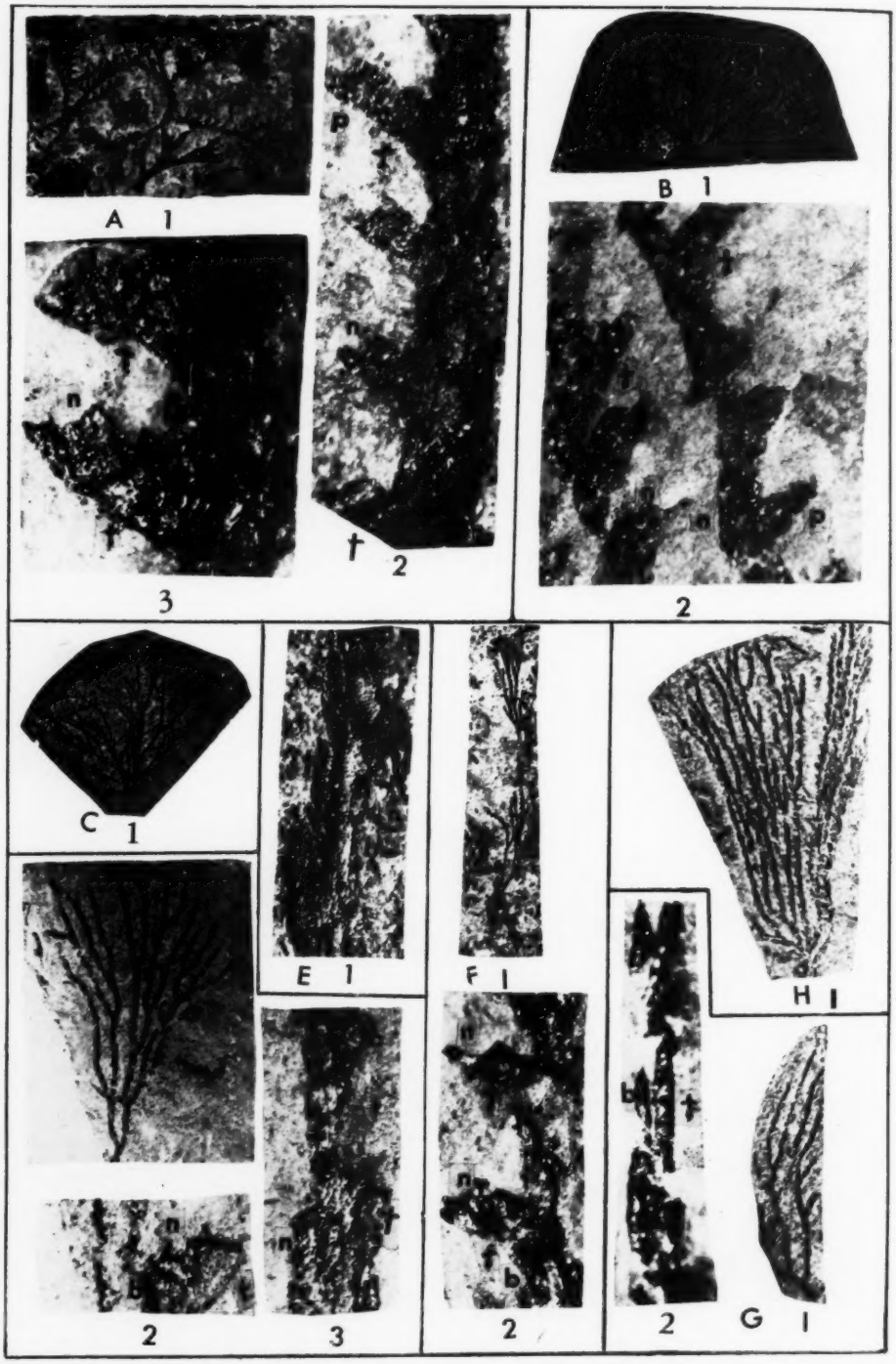
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Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLOGRAPTUS LOBELIATUS Decker & Gold, n. sp.
Pl. 56, figs. F1,2

The trivial name of this long, slender species is given because of its similarity to the brook lobelia. The colony is 43 mm. high and 7 mm. wide. Parts of the stipes are less than .25 mm. wide, but locally widen to .6 mm. Branching is irregular, varying from 3 to 6 mm. Thecae occur 14 in 10 mm. They are long and tubular and in parts of the colony they extend considerably beyond the margin of the stipes. Elongate, slender bithecae are present, several low broad gonothecae occur at the bifurcations, and nematothecae occur on the thecae and on the stipes. A stipe with two thecae is shown (fig. F2, ×20) at *t*, light colored bitheca to the right of *b*, and nematothecae on the thecae below *n*.

Remarks.—Another colony of this peculiar form was collected in 1938 from the Tecoy quarry by Joseph Bridge of the U. S. Geological Survey. His collection was loaned to the writer and the elongate colony was photographed, but it came too late to be used.

Type.—The colony described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLOGRAPTUS MILHOUSI Decker & Gold, n. sp.
Pl. 54, figs. D1,2,3

The trivial name of this new species is given in honor of Holman C. Milhous, geologist on the Tennessee Geological Survey, who assisted in collecting the graptolites from Tecoy quarry, Knox County, Tennessee. The colony is 38 mm. high and 28 mm. wide. The stipes are .2 to .6 mm. wide. The bifurcation intervals are 3 to 6 mm. The bifurcating angles vary from 3 to 15°. The spacing of stipes is very irregular, varying from 8 to 12 to 16 in 10 mm. with some vacant spaces 3 to 6 mm. wide. Thecae are tubular, and in some parts of the colony they extend beyond the margins of the stipes. They occur 16 in 10 mm. Only rarely can bithecae be seen. Gonothecae show at some of the bifurcations, and the ends of nematothecae protrude beyond the margins of some of the stipes. The colony is shown in figure D1 (×1) and in enlargements (fig. D2, ×17) with bithecae near *b* and nematothecae near *n*; the enlargement in figure

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EXPLANATION OF PLATE 56

Syrrhipidograptus and *Callograptus* from Tecoy quarry, Tennessee

FIG. *A*—*Syrrhipidograptus* sp. cf. *S. burkesgardenensis* Decker & Gold, n. sp. *A*, paratype. *A1*, colony (×2) showing elongate tubular thecae. *A2*, part of a stipe (×17) with elongate tubular thecae at high angle, thecae at *t*, nematothecae around thecal aperture, and the end of a calcified polyp extending out of thecal aperture. *A3*, part of stipe (×33) showing two large tubular thecae (*t*) with nematothecae on their surface and around aperture at *n*.

B,C—*Callograptus cooperi* Decker & Gold, n. sp. *B,C*, paratypes. *B1*, colony (×1). *B2*, part of two stipes (×17) showing thecae at *t* and nematothecae near *n*. End of calcified polyp extending out of thecal aperture. *C*, colony (×1) with shape typical of the holotype near Gratton, Virginia.

D,E—*Callograptus lilacus* Decker & Gold, n. sp. *D*, holotype. *D1*, colony (×2) showing thecae. *D2*, part of stipe (×32) showing theca at *t*, bitheca at *b*, and nematotheca at *n*. *D3*, part of colony or stipe (×17) showing bitheca at top to left of *b*, theca at *t* and nematothecae at *n*. *E*, paratype. *E1*, part of a stipe (×26) showing tubular theca parallel to stipe at *t*, bitheca left of *b*, and nematothecae near right edge above *n*.

F—*Callograptus lobeliatus* Decker & Gold, n. sp. *F*, holotype. *F1*, narrow colony (×1). *F2*, part of a stipe (×20) showing thecae at *t*, bitheca to right of *b*, and nematothecae on thecal apertures at *n*.

G—*Callograptus slenderatus* Decker & Gold, n. sp. *G*, holotype. *G1*, narrow colony (×2). *G2*, part of stipe (×17) showing long narrow thecae and bithecae at *b* and *t*. Tiny nematothecae show on surface.

H—*Callograptus staufferi bloomeri* Decker & Gold, n. var. *H*, paratype. *H1*, colony (×2) showing its form and theca in right part.

D3 (×36) shows a theca at *t* and a large hive-shaped gonotheca at *g*.

Remarks.—This colony is distinctive in the irregularity of its bifurcation angle 3 to 8°, and one over 30°, with marked variation in the distribution of its stipes, leaving large spaces between some of them.

Type.—This colony is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLOGRAPTUS SLENDERATUS Decker & Gold, n. sp.
Pl. 56, figs. G1,2

The trivial name of this new species is given because of its very long slender thecae and bithecae. Apparently this is not a complete colony, as a stipe seems to have been broken off from the left side. It has a height of 21 mm. and width of 7 mm. The branching interval is from 2 to 4 mm. and the angles about 20 to 30°. Stipes are .25 to .5 wide. The width is shown in figure G1 (×2). The colony is pyritized, and the periderm is exfoliated from large parts, revealing the long slender thecae and bithecae particularly well, as in figure G2 at *t* and *b*. Where the periderm is preserved, nematothecae protrude beyond the margins of the stipes. Thecae occur 12 in 10 mm. and they are 7 or 8 times as long as they are wide.

Remarks.—This colony is differentiated by its exceptionally long, slender thecae and bithecae which may be seen for long distances in parallel position on the exfoliated parts of the stipes.

Type.—This form is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLOGRAPTUS STAUFFERI var. BLOOMERI Decker & Gold, n. var.
Pl. 56, fig. H1; pl. 57, figs. A1,2

This new variety is described and illustrated above from Gratton, Virginia, by four colonies (pl. 49, figs. D1,2; E1,2,3; F1,2; G1,2). It is one of the most abundant and characteristic forms of that Virginia fauna. One Tecoy colony (pl. 56, fig. H1) shows the long slender, nearly parallel stipes characteristic of the new variety, with much of the periderm exfoliated, and on most stipes, tubular thecae and bithecae are parallel to the direction of the stipes, but on a few stipes the ends of thecae extend beyond the margins of the stipes. Where periderm is preserved, nematothecae occur around the apertures and on the sides of thecae, and on the surface of the stipes. It has the close spacing of the stipes, 13 to 16 in 10 mm., and short thecae characteristic of the new variety.

Another colony (pl. 57, figs. A1,2) has all the characteristics of the new variety described from Gratton, Virginia. It is 25 mm. high and 16 mm. wide. The elongate slender nearly parallel stipes are close together having 12 to 14 in the space of 10 mm. The bifurcation interval is long, 4 to 6 mm. or more. Thecae are tubular and most of them parallel with the stipes. Locally, some of them extend beyond the margin of the stipes. A few bithecae occur, and gonothecae show at some of the bifurcations. Nematothecae are well preserved around thecal apertures and on the surface of the stipes. Thecae occur 16 in 10 mm. The colony is shown in pl. 57, figs. A1 (×1) and A2 (×26). In A2 a theca is shown at *t*, bitheca to the left of *b*, a hive-shaped gonotheca to the right of *g*, a calcified polyp with nematothecae at *p*, and nematothecae on the stipe near *n*.

Remarks.—These colonies are two of several of this variety found at Tecoy quarry, showing that this new variety was well-developed here as well as at Gratton, Virginia.

Types.—Both colonies are designated paratypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus CALLODENDROGRAPTUS Decker, 1945

CALLODENDROGRAPTUS BORNI Decker & Gold, n. sp.
Pl. 57, figs. B1,2

The trivial name of this new species is given in honor of the late Kendall E. Born, former assistant geologist of Tennessee Survey. The colony is 21 mm. high and 14 mm. wide. The branching is very open with large bifurcation angles 15 to 20° or more. The stipes are wide, 1 to 1.5 mm. and up to 2 mm., just below the bifurcation. Thecae

and bithecae are parallel to the direction of the stipes. Thecae occur 12 in 10 mm. Gonothecae are present at some of the bifurcations. In figure B2 (×36), a large gonotheca shows at the left of *g*, theca at *t*, a calcified polyp with nematocysts around the aperture at *p*, and nematothecae on the stipe near *n*.

Remarks.—This colony is noted for its very open branching and broad stipes.

Type.—This form is the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLODENDROGRAPTUS BURWELLI Decker & Gold, n. sp.
Pl. 57, figs. C1,2

The trivial name of this new species is given in honor of H. B. Burwell, Director of the Tennessee Geological Survey. The colony is 35 mm. high and 11 mm. wide. It is a peculiarly shaped colony with 1 mm. broad main stipe with short irregularly spaced broad branches which are grouped more closely in the upper part. On the main stipe and some of the branches thecae show rather indistinctly. They occur 12 in 10 mm. On higher magnification (×36) bithecae show parallel to the thecae. Large hive-shaped gonothecae occur at the bifurcations, and where periderm is well preserved, nematothecae extend beyond the margins of the stipes.

Remarks.—The very broad stipes with short branches peculiarly distributed are distinctive.

Type.—The colony described above is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLODENDROGRAPTUS HOUSTONIATUS Decker & Gold, n. sp.
Pl. 57, fig. D1,2

The trivial name of this new species is given because it branches like the long-leaved *Houstonia*. The colony is 33 mm. high and 18 mm. wide. The branching is rather open with the angle varying from 6 to 40°. The stipes are very narrow, being .2 to .4 mm. wide. The branching interval is 3 to 6 mm. Thecae are tubular, and on some stipes they extend considerably above the surface at a high angle. They occur 14 in 10 mm. Bithecal apertures occur near the base of the thecae, or in some cases, a short distance up on their sides. Gonothecae occur at some of the bifurcations, or as enlarged swellings along the course of the stipes. Nematothecae occur around the apertures and on the sides of the thecae, and on the surface of the stipes. Thecae show at a high angle on the stipes (figs. D1, ×2; D2, ×28). Thecae show above *t* with the calcified ends of two thecal polyps protruding out of the thecal apertures at *p*, a calcified polyp at the upper *p* with nematocysts around its aperture, and a gonotheca to the right of *g* with large open aperture.

Remarks.—This large colony has tubular thecae like a *Callograptus* and branching like a *Dendrograptus* so it fits well in the genus *Callodendrograptus*.

Type.—This colony is designated the holotype.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLODENDROGRAPTUS SELLARDSI Decker
Pl. 57, fig. E1; F1,2,3

Callodendrograptus sellardsi Decker 1945, p. 30.

A colony from Virginia is shown in pl. 51, figs. E1,2,3.

Two somewhat similar colonies differing in branching are used to illustrate this species. The colony shown in figure E1 (×1) has branches on the left of the main stipe with one of them exceptionally long, while the colony shown in figure F1 (×1) has its branches on the right. This latter colony is 28 mm. high and 11 mm. wide. The branching intervals on the upper part are 2 to 3 mm., the main stipe is 1 mm. wide, and the branches are .5 mm. wide. In figure F2 (×17), a large, dark, hive-shaped gonotheca is shown on the left margin opposite *g*, and a calcified end of a polyp protruding out of the thecal aperture at *b*. In the much enlarged figure F3 (×33) a bitheca can be seen in the lower part to the left of *b*, nematothecae to the left of *n*, theca at *t*, a calcified polyp with nematocysts at *p*, theca above at *t* with calcified polyp protruding out of its aperture at *p*, and theca with nematothecae at the top (*t*, *n*).

Remarks.—This species of *Callodendrograptus sellardsi* is well developed in the

upper zone at Gratton, Virginia, and is especially common and highly developed in the Upper Cambrian Wilberns formation near Mason, Texas, from which the original specimens of the genotype were obtained and nine different colonies of the species illustrated.

Types.—The two colonies illustrated here are designated ideotypes.

Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

CALLODENDROGRAPTUS SELLARDSI var. EXPANSUS Decker

Pl. 58, figs. A1,2,3; B1,2,3

Callodendrograptus sellardsi expansus Decker, 1945, p. 30, pl. 4, figs. 4,6; pl. 7, fig. 8; pl. 8, figs. 2–4.

A colony from Virginia is shown in pl. 51, figs. F1,2,3.

This first small branching colony is 16 mm. high and 13 mm. wide. The branching interval is 2 to 3 mm. and the bifurcation angles 8 to 20°. The basal stipe is 1 mm. wide and branches are .7 mm. wide. Thecae occur 16 in 10 mm. Only a few bithecae can be seen, and several gonothecae occur at the bifurcations. Nematothecae are scattered over the surface of the stipes. The colony is shown in figure A1 (×1). An enlargement of part of stipe (fig. A2, ×17) shows a gonotheca at the bottom to the left of *g*, a bitheca above *b*, and nematothecae at left on the stipe above and below *n*. A second enlargement of a branching stipe (fig. A3, ×17) shows gonotheca to the right of *g* near the bottom and near the middle below the bifurcation to the right of *g*, a bitheca to the left of *b*, and nematothecae at both sides of *n* near the top, and to the left of *n* on the right side.

A second colony of this variety is shown in figure B1 (×2) in which the basal stipe uniting the two branching parts is missing. Thecae may be seen at the left above *t* and on the upper edge of the main stipe at the right. The part of the colony preserved is 18 mm. high and 26 mm. wide. The main stipe is 1 mm. wide and the branches .7 mm. wide. Branching is open with angles of 15 to 25°. Branching intervals are small in the upper part, only 2 to 3 mm. Thecae occur 14 in 10 mm. Bithecae show at a few places, and gonothecae occur below the points of bifurcation. Part of the colony is pyritized. In figure B2 (×17) a gonotheca shows at the left of *g*, a calcified polyp above *p*, and nematothecae on the stipe to the right of *n*.

In figure B3 (×28) a broad gonotheca occurs to the right of *g* and nematothecae on the stipes both sides of *n* in the angle.

Remarks.—Of the two colonies of *expansus* illustrated, the second one is the most typical.

Types.—The two colonies described above are ideotypes.

EXPLANATION OF PLATE 57

Callograptus and *Callodendrograptus* from Tecoy quarry, Tennessee

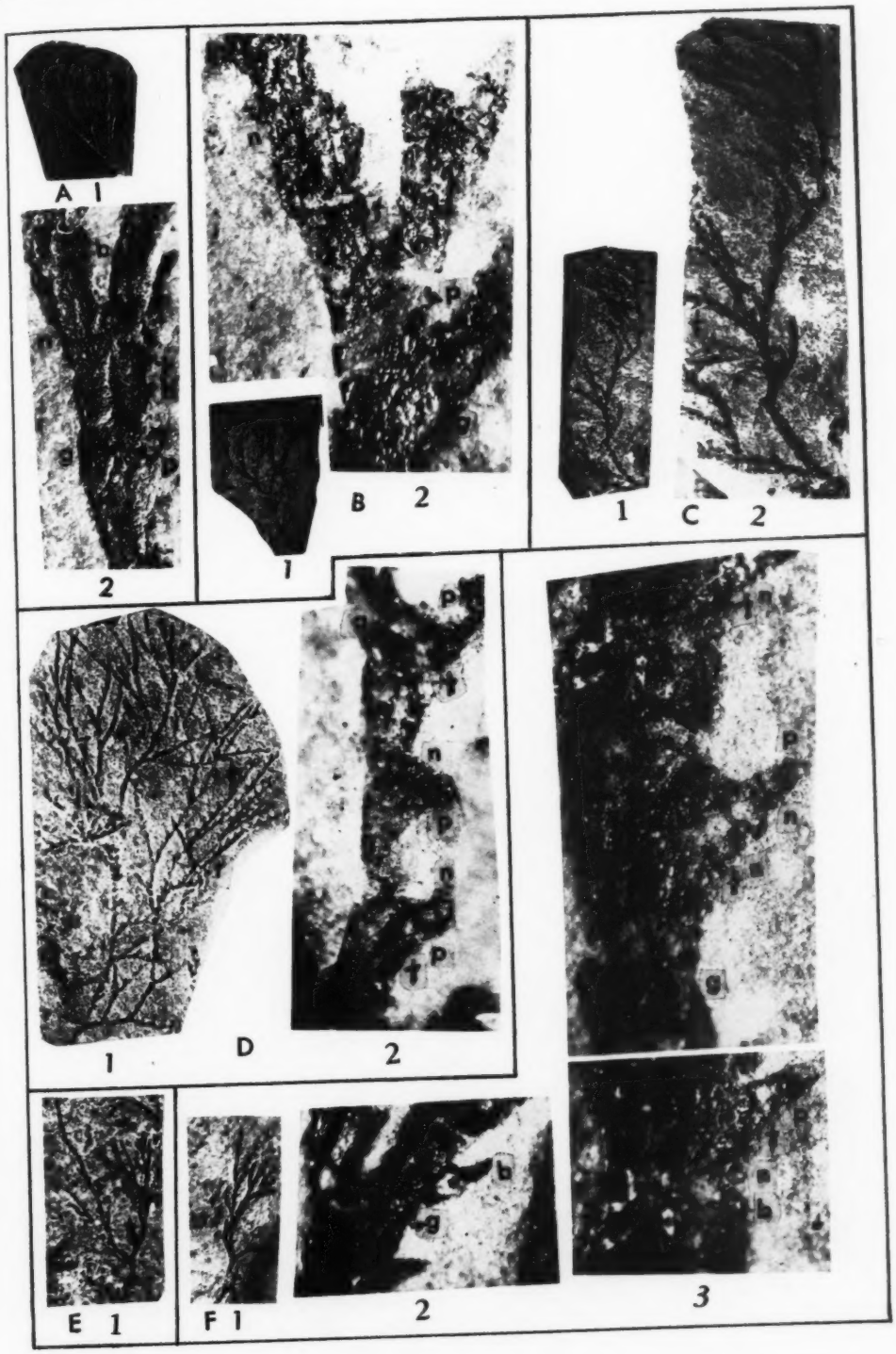
FIG. *A*—*Callograptus staufferi bloomeri* Decker & Gold, n. var. *A*, paratype. *A1*, colony (×1). *A2*, part of branching stipe (×26) showing thecae to left of *t* and *b*, bithecae to right of *b* and to right of stipe, gonotheca at *g*, nematothecae on stipe near *n*, and the calcified end of a polyp extending out thecal aperture (*p*).

B—*Callodendrograptus borni* Decker & Gold, n. sp. *B*, holotype. *B1*, colony (×1). *B2*, branching stipe (×32) shows large gonotheca at *g*, theca at *t* with bitheca on its side, and nematothecae scattered over surface of stipe and to right of *n*.

C—*Callodendrograptus burwelli* Decker & Gold, n. sp. *C*, holotype. *C1*, colony (×1). *C2*, colony (×2) showing points of thecae on main stipe and above *t*.

D—*Callodendrograptus houstoniatus* Decker & Gold, n. sp. *D*, holotype. *D1*, colony (×2) showing thecae. *D2*, part of a stipe (×28) showing thecae at *t*, gonotheca to right of *g*, ends of calcified polyps at lowest and middle *p*, complete calcified polyp with nematothecae on it at upper *p*, and nematothecae at *n*.

E,F—*Callodendrograptus sellardsi* Decker. *E,F*, ideotypes. *E1*, colony (×1) showing long left branch, and branches on left. *F1*, colony (×1) with branches chiefly on right side. *F2*, part of branching stipe (×17) showing large dark gonotheca to left of *g* in bifurcation position, elongate calcified bithecal polyp at *b*. *F3*, part of stipe (×33) showing dark gonotheca to left of *g*, thecae above each *t*, bitheca at *b*, ends of calcified polyps extending out of the thecal apertures *p*, and nematothecae near *n*.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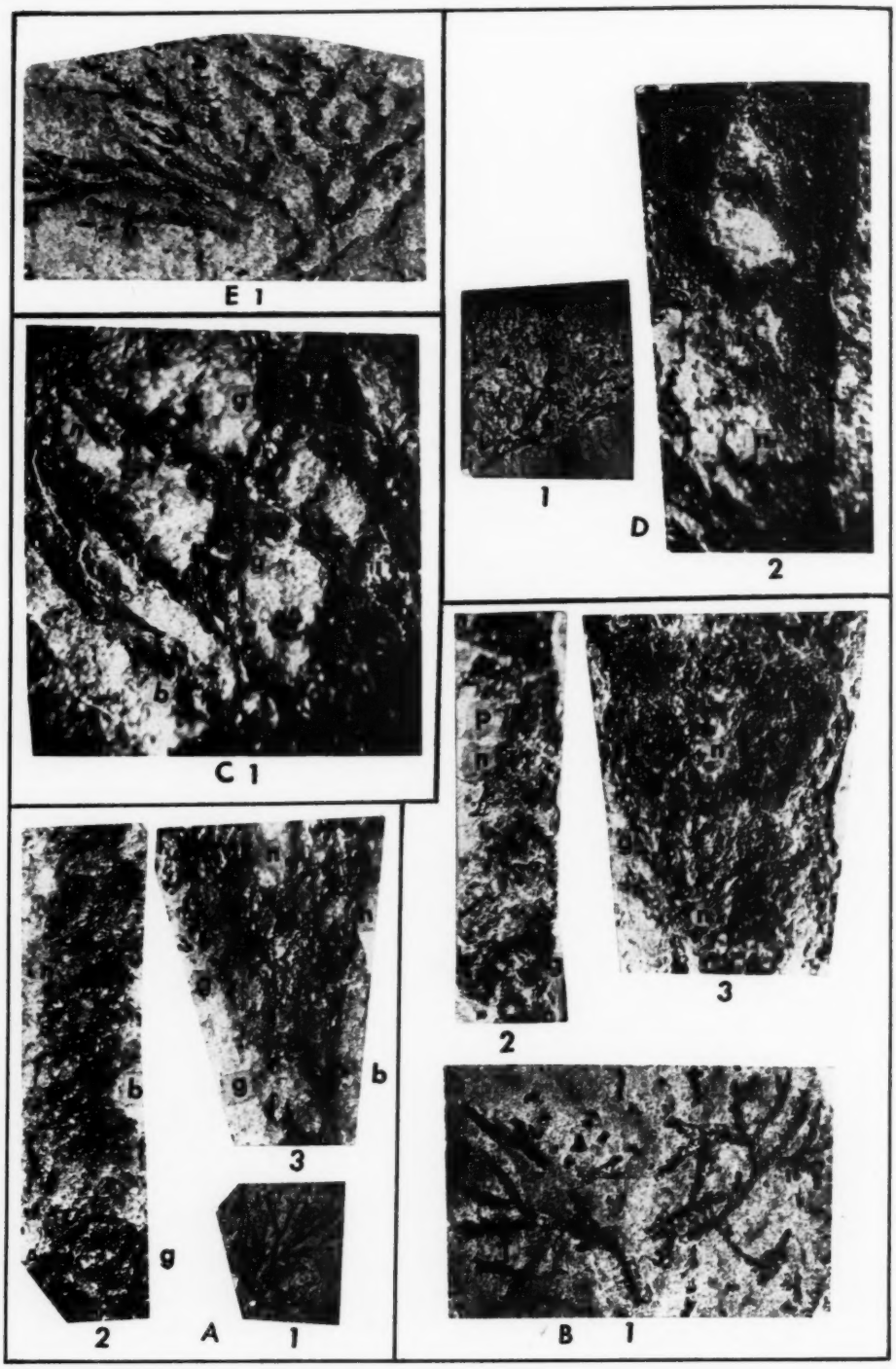
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Repository.—Museum of Invertebrate Paleontology, University of Oklahoma.

Genus DICTYONEMA Hall, 1951
DICTYONEMA sp. A
Pl. 58, fig. C1

A small part of a colony shown in figure C1 (×17) has diamond shaped fenestrules, the larger ones measuring 1 to 1.5 mm. in length. In the lower part of bitheca shows above *b*, two gonotheca show to the left of the lower *g* and to the right of the upper *g*, and nematothecae at upper left on the stipes both sides of *n*.

DICTYONEMA sp. B
Pl. 58, figs. D1, 2

A largely exfoliated part of what is thought to be a young colony is shown in figures D1 (×1) and D2 (×17). This fan-shaped colony is 20 mm. high and 26 mm. wide at top. The main stipe is 1 mm. wide and the branches .5 mm. wide. The branching stipes spread laterally with irregular spaces between them. The stipes had the remarkable anastomosing power of lateral growth to largely fill in the spaces between them, leaving small irregular spaces or fenestrules of varying shape, elongate, oblong, or nearly round. A branch at the right near the base has saw-toothed thecae. They occur 12 in 10 mm. Elongate barrel-shaped gonothecae occur at some points along the stipes and (fig. D2, ×17) some nematothecae show on the surface near *n* along the lower left margin.

DICTYONEMA sp. C
Pl. 58, fig. E1

This third colony of *Dictyonema* shown in figure E1 (×4) has parts of the top, bottom and right side broken off on the irregular surface of the limestone. In the right part, the curving branches grow together to enclose fenestrules, while branches in the left part grew nearly straight with no tendency to enclose fenestrules, so this form seems to illustrate a very early stage in forming a *Dictyonema*.

REMARKS ON DICTYONEMA

Concerning the development of *Dictyonema* in the Upper Cambrian only parts of three colonies have been illustrated from Tennessee. Only small fragments, too poor to be photographed, were seen from the upper zone near Gratton, Virginia. Only fragments of colonies were illustrated by Ruedemann (1933, p. 321,323; pl. 52, figs. 9,10; p. 55, fig. 3, text-figs, 1–4).

Parts of five very irregular *Dictyonema* colonies from the Upper Cambrian of Texas were illustrated (Decker, 1954, pl. 5, figs. 2–4, 7–10) from the Wilberns Upper Cambrian formation of Texas. The evidence from all of these states indicates that at these early horizons *Dictyonema* colonies were irregular with many of them in early stages of development. The poor showing for this genus is in strong contrast with the many species of well preserved colonies of *Dendrograptus* and *Callograptus*.

EXPLANATION OF PLATE 58

Callodendrograptus and *Dictyonema* from Tecoy quarry, Tennessee

FIGS. *A,B*—*Callodendrograptus sellardsi expansus* Decker. *A,B*, ideotypes. *A1*, colony (×1). At lower left corner. *A2*, part of stipe (×17) showing gonotheca to left of *g*, theca at *t*, bitheca above *b*. *A3*, branching stipe (×17) showing gonotheca to right of each *g*, bitheca to left of *b*, nematothecae over surface of stipes. *B1*, colony (×2) showing thecae on some stipes as at *t*. *B2*, part of a stipe (×17) showing gonotheca to left of *g*, calcified end of polyp with nematothecae on it above *p*, nematothecae on stipe to right of *n*. *B3*, branching stipe (×28) showing large, low gonotheca at right of *g* and nematothecae on lower part of stipe near *n* and both sides of *n* higher up.

C—*Dictyonema* sp. A. Part of a colony (×17) showing large and smaller fenestrule openings, showing gonotheca in the middle to left of *g*, and higher up to right of *g*, bitheca above *b* and nematothecal ends near *n*.

D—*Dictyonema* sp. B. *D1*, lower part of exfoliated colony (×1). *D2*, small part of colony (×17), showing irregular fenestrules, nematothecal ends below *n*.

E—*Dictyonema* sp. C. Large part of colony (×4) showing long, and oblong, fenestrules in part at right with none in left half. Irregular thecae show on some stipes.

Noteworthy also is the presence of *Syrrhipidograptus* and *Callodendrograptus*.

CONCLUSION

Higher magnification of these Upper Cambrian graptolites has definitely shown not only thecae and bithecae, but also the new structures, gonothecae and nemathecae, which with many other characacteristics seem clearly to associate graptolites with Coelenterata rather than with Hemichordata.

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SOME CHAZYAN AND MOHAWKIAN ENDOCERATIDA

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ABSTRACT—Evolution in the Endoceratida is outlined, and division of the adequately known families into the new suborders Proterocameroceratina and Endoceratina is proposed, the Proterocameroceratina containing the Proterocameroceratidae, Manchuroceratidae, Emmonsoceratidae, Chihlioceratidae and Allotrioceratidae, the Endoceratina containing the Piloceratidae, Endoceratidae and Cyrtendoceratidae. The new families Cyrtovaginoceratidae and Narthecoceratidae remain of uncertain affinities. New genera include *Emmonsoceras*, *Vaningenoceras*, *Triendoceras*, and *Chazyoceras*. New species are *Vaningenoceras styliforme*, *V. indomitum*, *Lamottoceras franklini*, *Chazyoceras valcourense*, *Endoceras microlobatum*, *Triendoceras montrealense*, *T. orthoseptatum* and *Cyclendoceras clarki*.

INTRODUCTION

THIS is a further contribution to our still very incomplete knowledge of the Endoceratida. As noted previously (Flower, 1955), exceptional difficulties stem from the fragmentary nature of typical endoceroid specimens. Species and genera have been based upon forms known only from shell surfaces, again from endosiphuncles, or from apical portions of the shell. Some genera thus differentiated should never have been named, but there are others which are obviously distinct from any other known endoceroids, and some of them have been found to have some faunal and stratigraphic value.

While some obviously valid genera remain so little known that their relationship to other genera in the Endoceratida must remain uncertain, it is possible to trace the general evolutionary development in the order. It was soon found (Flower, 1947) that there were three very significant groups. A primitive group, the Proterocameroceratidae, embraces slender Canadian genera and a few in the Chazyan, and is characterized in general by a siphuncle small and slender from its beginning, and short septal necks. A second group, the Piloceratidae, retained simple cones but developed holochoanitic necks in the Canadian, here treated as a system apart from the Ordovician. The slender Endoceratidae agree with the Piloceratidae internally, and developed from them, rather than from the slender Canadian Proterocameroceratidae which they resemble more closely in form. Subsequent studies indicated that the Proterocameroceratidae contained a diversity of forms, showing such structural differences that a single family was hardly adequate to embrace its varied genera. The Chihlioceratidae and Manchuroceratidae contained some derived types, and the family Allotrioceratidae was erected for some others. Even so, the present Proterocameroceratidae contains both primitive and specialized forms; and the specialized ones clearly represent several divergent lines of descent. Quite probably the family will be even more restricted with further study. Nevertheless, recognition of this entire lineage is significant, and it is proposed here to designate it as the suborder Proterocameroceratina, leaving the Piloceratidae, Endoceratidae and Cyrtendoceratidae constituting the suborder Endoceratina.

FAMILIES OF THE ENDOCERATIDA

Suborder PROTEROCAMEROCERATINA, n. suborder

Endoceratida having the siphuncle small and slender and surrounded dorsally and laterally by camerae from its inception, primitively with short septal necks. Endosiphuncles range from those of extreme simplicity, to those which are most elaborately specialized. Stocks in which the siphuncle is already highly modified may produce shells which are depressed brevicones, or may develop long spetal necks, like those of the Endoceratina.

Family PROTEROCAMEROCERATIDAE

Shells dominantly slender, straight or slightly curved, septal necks never long

enough to be called holochoanitic. Endosiphuncles range from those of extreme simplicity with circular cones and a central tube, but without well developed blades, to extremely complex ones. The family ranges from early Middle Canadian through the Chazyan. As at present understood, the family is a large and heterogenous one, including primitive types and many divergent lines of specialization. Some specialized types have been distinguished and comprise the succeeding families, but others, at present retained in the Proterocameroceratidae are equally distinctive. Extensive material now being studied promises to add materially to the knowledge of the genera currently recognized, and will probably supply some new ones. It therefore seems that at the present time any attempt to restrict the family further would be premature.

Family MANCHUROCERATIDAE Kobayashi

Dominantly breviconic shells, with both shell and siphuncle broader than high in cross section; endocone material thickened ventrally so that the endosiphocone is crescentic, concave ventrally, convex dorsally. Upper Canadian. Here are placed only two genera, *Coreanoceras* and *Manchuroceras*.

Family EMMONSOCERATIDAE Flower, n. fam.

Endoceroids with endosiphuncles similar to those of the Manchuroceratidae in general organization, but differing in that shells are large and slender, and septal necks extend for more than the length of one camera. This family is here erected for the sole reception of the genus *Emmonsoceras* Flower. *Emmonsoceras* is a new name here proposed for *Hudsonoceras* Flower (1955*a*, p. 351, not Moore, 1946, Yorkshire Geol. Soc., Proc., v. 25, p. 433). I am indebted to Dr. Frank Hodson of the University of Reading for calling to my attention this previous use of the generic name *Hudsonoceras*. *Emmonsoceras* is known only from the Chazyan. It is quite clearly a descendant of the Manchuroceratidae, with which it was originally placed. This family is not indicated in text-fig. 1, except as an extension of the Manchuroceratidae into the Chazyan.

Family CHIHLIOCERATIDAE Grabau

Breviconic endoceroids of depressed section, the siphuncle broad, with two lateral endocones in addition to a larger central one. Known only from *Chihlioceras*, of the late Canadian of north China.

Family ALLOTRIOCERATIDAE Flower

Siphuncles in which coenogenetic structures, a lining with a forked partition or a central pillar, precede endocones in ontogeny. The endocones are modified to conform to the resulting pattern, and terminate, at least apically, in multiple endosiphotubes. Known only from *Allotrioceras* and *Mirabiloceras* of the Chazyan.

Suborder ENDOCERATINA

Endoceratida with holochoanitic septal necks, cones which are but little modified in cross section, endosiphotube largely central. Siphuncle large apically, may occupy all of shell apex.

Family PILOCERATIDAE

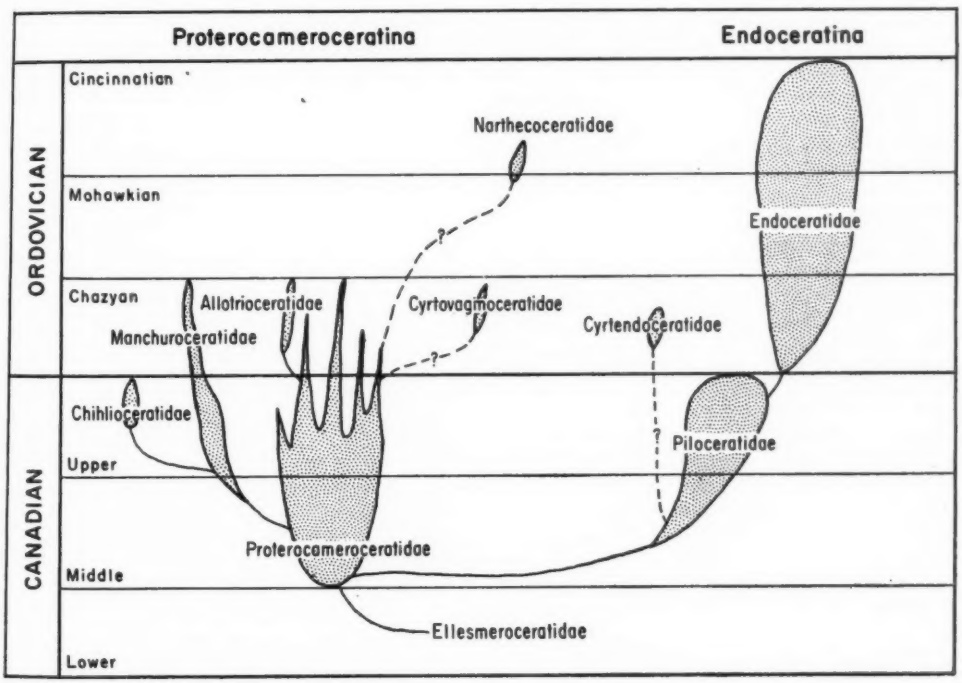
Breviconic shells, shell and siphuncle both compressed in cross section, septal necks holochoanitic, endosiphuncle relatively simple. This family is presumably derived from the simpler Proterocameroceratidae, and makes its appearance in late Middle Canadian time, extending to the close of the period. As yet, no forms transitional between the Proterocameroceratidae and the Piloceratidae have been recognized. Siphuncle large apically, apical camerae may be eliminated in some forms; anterior parts of shells and siphuncles are more slender, often tubular; some forms have living chambers with slightly contracted aperatures.

Family ENDOCERATIDAE Hyatt

Shells large, straight, depressed in section in the adult. Young stages compressed in section, the siphuncle large, primitively swollen, and may occupy all of shell apex; endosiphuncles relatively simple in construction. The family is known to range from Chazyan to the close of the Ordovician, is possibly present in Whiterock strata.

Family CYRTENDOCERATIDAE Hyatt

This family was erected for the genus *Cyrtendoceras* alone, a strongly curved endogastric endoceroid, known from a few species, and apparently from almost as few specimens, from the upper Red Orthoceras limestone of the Baltic region. The subsequent discovery of true Endoceratidae which are very slightly curved, supplies something of a transition from typical straight Endoceratidae to this genus. For this reason, I omitted the family Cyrtendoceratidae in my former treatment of the endoceroids, placing *Cyrtendoceras* in the Endoceratidae. A new form, to be described elsewhere as the new genus *Bisonoceras*, suggests a possible origin of *Cyrtendoceras* in the Piloceratidae. This genus occurs in the first piloceroid zone of the El Paso limestone (Flower, 1953), of late Middle Canadian age. On one hand, this form is little more than a *Piloceras* which is gyroconic rather than cyrtoconic; on the other, it is little more than a *Cyrtendoceras* which is extremely rapidly expanding, both as to shell and siphuncle. It supplies a potential link between *Cyrtendoceras* and the Piloceratidae. Even so, I was at first inclined to consider the resemblance between this new form and *Cyrtendoceras* homeomorphic, largely because of the apparently large stratigraphic gap involved, for it was then believed that the strata yielding *Cyrtendoceras* were of either Chazyan age or slightly younger. While *Cyrtendoceras* is of somewhat dubious range, as are, indeed most of the described cephalopods of the Baltic Ordovician, many forms having been described from drift boulders of northern Germany, it now appears the the stratigraphic gap need not be as large as was formerly believed, for the upper Red Orthoceras limestone is, from other evidence, at least in part equivalent to the Whiterock of North America (see Cooper,



TEXT-FIG. 1—Evolution of the Endoceratida, showing relationship and range of the more important families. the division into the suborders Proterocameroceratina and Endoceratina, and doubtful origin of the Cyrtovaginoceratidae and Narthecoceratidae.

1956), and thus older than the true Chazyan. *Cyrtendoceras* has holochoanitic necks, like those of both the endoceratidae and Piloceratidae. A piloceroid feature is the compressed cross section of the shell, found only in the early growth stages of the Endoceratidae. Only the extreme anterior end of the endosiphuncle has been observed in the genus, just enough to demonstrate that it is a true endoceroid. The cones appear circular in section. As it now seems probable that *Cyrtendoceras* sprang from the Piloceratidae instead of being only a strongly curved member of the Endoceratidae, it seems proper to recognize the family Cyrtendoceratidae.

ENDOCEROIDS OF UNCERTAIN POSITION

As noted above, a number of endoceroid genera are so incompletely known that their position within the Endoceratida cannot be determined precisely. For Canadian genera, the problem is not a serious one, for the known Endoceratida comprise only the compressed breviconic Piloceratidae, while shells which are slender or depressed in section are quite clearly members of the Proterocameroceratina. However, the problem is much more difficult is relation to genera of Chazyan or younger age, for the two stocks become homeomorphic to some degree, enough so to be perplexing for practical purposes. Two Ordovician genera, *Cyrtovaginoceras* and *Narthecoceras*, are so distinctive that new families are erected for them. The present incomplete evidence favors an origin in the Proterocameroceratina for both of these stocks, but is not conclusive.

Mention should be made of a number of proposed family groups which are considered invalid. The family Suecoceratidae was erected a group of genera in which the siphuncle is more or less swollen apically. Two of its genera, *Suecoceras* and *Nanno*, are good members of the Endoceratidae. *Proterocameroceras* is the type genus of the Proterocameroceratidae. It is doubtful whether the apical swelling of the siphuncle reported in this genus is real. *Subpenhsioceras* Shimizu & Obata is based upon an endosiphuncle so little known that its position can at present be only a matter of guesswork. The family Hemipiloceratidae is not employed here, because its type genus *Hemipiloceras* is too inadequately known to give any indication of its position in the Endoceratida. The family Cyclendoceratidae, erected for annulated endoceroids, is clearly not a natural group. *Anthoceras* Teichert & Glenister is an annulated endoceroid belonging to the Proterocameroceratidae. Annuli seem an insufficient reason for distinguishing *Cyclendoceras* from the Endoceratidae. The endosiphuncle and siphuncle wall are made known for *Cyclendoceras* for the first time in the present paper.

Family CYRTOVAGINOCERATIDAE
Flower, n. fam.

Only endosiphuncles of this genus are known, but they are unlike those of any other endoceroids in form. They begin with blunt tips, are slender for an appreciable interval, and then suddenly become markedly rapidly expanding. Still later, they may again become more slender. Little is known of the endocones; presumably they conform to the cross section of the siphuncle. Clearly, they terminate in a subcentral tube. Siphuncle wall, septa and shell are as yet unknown. One may, indeed, wonder whether the shell shows the same peculiar variations in expansion as does the siphuncle. *Trifurcatoceras* Obata was based upon one growth stage of siphuncles of this type, in which the endosiphocone happened to occupy the adoral more rapidly expanding part of the siphuncle. Curiously, the same author described other growth stages of very similar forms as *Endoceras yabei* and *E. hayasakai*. The genus is known from the Toufangian of eastern Asia and the Chazyan of the Champlain Valley.

The relative simplicity of the endocones suggests origin of this stock in the Endoceratidae. However, the older Endoceratidae are uniform in having the apical part of the siphuncle markedly swollen, and contrast in this respect strongly with *Cyrtovaginoceras*. However, simplicity of endocones is not a feature which excludes a genus automatically from the Proterocameroceratina. *Lamottoceras*, clearly a member of that lineage, has relatively simple cones. On the other hand, the slender and uniformly enlarging apical part of the siphuncle is a feature at

variance with the older Endoceratidae, and one consistent with the Proterocameroceratinae. It is therefore believed that the Cyrtovaginoceratidae stem from the Proterocameroceratina, and probably from the Proterocameroceratidae.

Family NARTHECOCERATIDAE

Only endosiphuncles of this family are known. They are straight, slender, very gently enlarging, marked by distant narrow constrictions between which the siphuncle may show slightly convex outlines. Endocones are subcircular, terminate in a central tube which is commonly traversed by diaphragms. The sole occupant of this family is the genus *Narthecoceras*, which is known only from Red River faunas of northern North America, ranging from Winnipeg to northern Greenland.

Some other endoceroids, notably *Kotoceras cylindricum* and *Lamottoceras nodosum*, are known to show broad low undulate markings which clearly have nothing to do with the closely spaced septa. In *Narthecoceras* the constructions between the annular expansions are much more sharply incised, there are no finer markings which might represent more closely spaced septa, and it is probable that *Narthecoceras* did possess extremely distant septa. If so, it is unique among the Endoceratida in this respect.

Two considerations suggest origin of *Narthecoceras* in the Endoceratidae. Its occurrence in Red River faunas leaves it stratigraphically isolated from the last of the definitely recognized members of the Proterocameroceratina. The simplicity of the endocones in cross section is a feature which also suggests the Endoceratidae. However, other evidence suggests origin in the Proterocameroceratina. Diaphragms in the siphuncle are found not uncommonly in that stock. In the Endoceratina they are known only in a few of the Piloceratidae, but not in any of the Endoceratidae. Although no specimen has been recognized as representing the apex of the siphuncle of *Narthecoceras*, a number of specimens must lie close to it. They fail to show any indication of an apical swelling such as characterizes the Endoceratidae. It therefore seems that the present evidence, while admittedly inconclusive, favors origin of this family in the Proterocameroceratina. Indeed, *Vaningenoceras* of the Chazyan, described in the following pages, has a siphuncle with cones but little modified from the circular in cross section, diaphragms in the siphuncle, a slender apex, and needs only an annular exterior of the siphuncle to resemble *Narthecoceras*.

STRATIGRAPHIC SUMMARY OF THE ENDOCERATIDA

The stratigraphic range of the main families of the Endoceratida is shown in text-fig. 1. It remains to note something of the faunal and stratigraphic value of various of the groups, and to add some generalizations which have been found useful stratigraphically, as well as in the collection and treatment of the specimens.

Canadian

The Canadian, here treated as a system distinct from the Ordovician, is marked by the first great expansion of the cephalopods. The cephalopods expanded rapidly in the Canadian and developed a number of distinctive forms. In the Ordovician above, one finds few survivors of Canadian cephalopod stocks, and those few known are, for the most part, considerably modified. As previously noted (Flower, 1954), no genera or species pass the Canadian-Ordovician boundary, only a few families survive unchanged, and there are marked differences of ordinal as well as of family rank.

No Lower Canadian Endoceratida are known. Instead the Lower Canadian is marked by the prolific expansion of the Ellesmeroceratidae, the stock from which the endoceroids were derived. Indeed, the first endoceroids differ from straight-shelled genera of the Ellesmeroceratidae primarily in the suppression of diaphragms and the development instead of endocones. The first known endoceroids occur in beds of very early, probably earliest Middle Canadian age. Their siphuncles are slender from the very beginning, surrounded dorsally and laterally by septa; the septal necks are short, the endocones circular in section, terminate in a subcentral tube, and blades are poorly developed or wanting. However, specializations soon developed. The Proterocameroceratidae of the late Middle

Canadian have become appreciably more specialized in the organization of the endosiphuncle (see Flower, 1956*a*) and in form. Some shells became cyrtoconic, as in *Clitendoceras, Kirkoceras* and *Oderoceras. Escharendoceras* has an asymmetrical siphuncle, suggesting a shell in which curvature departs from the plane of symmetry. Necks may lengthen; in *Proendoceras* and *Clitendoceras* necks are very short in the young, but extend for about half the length of the camerae in late growth stages. *Mcqueenoceras*, a slightly curved endoceroid with the endocones of the siphuncle projecting forward into a flat blade on the venter, is particularly characteristic of the earliest Upper Canadian. It is in the Upper Canadian that Proterocameroceratidae are found in which the cones become highly modified in cross section and definite and varied patterns are formed by specialization of the blades.

Two distinct stocks stemming from the Proterocameroceratidae became breviconic. One, the Piloceratidae, is characterized by shells of compressed section and holochoanitic necks, while endocones remain simple in pattern. The true Piloceratidae are known to range from late Middle Canadian to the close of the period. They range geographically from Scotland through North America. Teichert (1947) has recorded a specimen from Tasmania, but the stock is unknown in north China and Manchuria.

The Manchuroceratidae, on the other hand, represent the development of breviconic shells in which the cross section is depressed, the endosiphuncle is quite highly specialized, but in which, as far as is known, the septal necks remain short. *Chihlioceras* is apparently allied, and is thus far reported only from north China. Kobayashi (1934, 1935, 1936) has discussed these stocks on the basis of typical material from eastern Asia. Teichert (1947) recognized *Manchuroceras* in Tasmania. Flower (1956*a*) has recognized *Coreanoceras* in eastern North America. In bringing together material for the study of the endoceroids of the El Paso limestone, some possible Manchuroceratidae have been encountered. One specimen, received from the U. S. Geological Survey, proves to be a *Chihlioceras*, but unfortunately while it is believed to come from the El Paso succession, its origin is dubious, and thus far further collecting has failed to bring another similar form to light. Rather large slender endoceroid siphuncles from the upper part of the Garden City limestone have the internal structure of *Coreanoceras*.

The close of the Canadian marks the disappearance of the known breviconic endoceroids. The Proterocameroceratina survive, being represented by slender shells with highly specialized endosiphuncles. Current observations indicate that identifications can often be made on the basis of isolated siphuncles, which are far commoner in many Canadian strata than are complete shells, and that genera so characterized have an appreciable value as horizon markers there.

Whiterock

Cooper (1956) has recognized as the Whiterock an interval following the close of the Canadian and preceding the true Chazyan. It contains endoceroids, but as yet little is known of those found in North American faunas. Some material recently received or collected, indicates that there are here some highly specialized siphuncles evidently belonging to the Proterocameroceratina, and some of very generalized organization, which may represent the first of the true Endoceratidae. Other considerations suggest that the upper Red Orthoceras limestone may be of Whiterock age. If so, *Dideroceras* may belong in this interval. Generalization in this matter is difficult, however, because in the present literature at least, the stratigraphic position of many of the crucial genera and species in the Baltic and Scandinavian regions is yet uncertain; many species were described from material from drift boulders, and others were collected long ago and the published stratigraphic data is often inadequate. In any case, the Orthoceras limestone faunas contain endoceroids quite unlike any of those known in North American Whiterock associations.

Chazyan

Only in the type section of the Chazyan in the Champlain Valley are endoceroids of Chazyan age at all adequately known. The endoceroids are all straight shells, moderate to large in size, generalized externally, but

widely diverse as to internal structure. There is a group of forms here with highly complex endosiphuncles, evidently belonging to the Proterocameroceratina, but with them are found the oldest species which can be assigned to the Endoceratidae with certainty, those of the Whiterock being probable but little more. The Chazyan endoceroid association differs from that of the Candian below in the presence of Endoceratidae and the absence of Piloceratidae, and from beds above in which no Proterocameroceratina are known.

The lower Chazyan has yielded few endoceroids, none well enough preserved or complete enough to be studied properly. An apical end of the *Nanno* type has been figured (Flower, 1955a) and some fragments of relatively large endoceroids have been collected, but none of the larger fragments were well enough preserved for proper study.

The middle and upper Chazyan has yielded a number of forms belonging to the Proterocameroceratina: *Meniscoceras coronense* Flower, 1941, *Lamottoceras ruedemanni* Flower, 1955*b*, *L. nodosum* Flower, 1955*b*, *L. franklini* Flower, n. sp., *Vaningenoceras styliforme* Flower, n. sp., *V. indomitum* Flower, n. sp., *Emmonsoceras aristos* Flower, 1955*a*, of the new family Emmonsoceratidae, and the two known genera and species of the Allotrioceratidae, *Allotrioceras bifurcatum* and *Mirabiloceras multitubulatum*. The Allotrioceratidae, unique in their highly modified endocones and multiple endosiphotubes, are known only from the Chazyan.

The associated Endoceratidae are less adequately known. They all have holochoanitic septal necks, apices of the *Nanno* type, and endocones which are but little modified from the subcircular cross section of the siphuncle. They do show that some specializations have taken place already in the stock, and the following types can be recognized. (1) Cones faintly compressed, rounded dorsally, pointed ventrally as in *Vaginoceras*, but with more than the two vertical blades found in that genus. Indeed, the Chazyan forms show some variation in the number and arrangement of the blades difficult as yet to evaluate as erratic, ontogenetic or specific in significance. *Vaginoceras oppletum* Ruedemann belongs to this group, but apparently there is more than this single species involved. This group will be studied more thoroughly later. It is regarded as a possible forerunner of *Vaginoceras*, but should probably be separated from that genus. Its apical end was described as *Nanno noveboracum*. (2) Forms with the cones slightly depressed, terminating close to the ventral wall of the siphuncle, typified by *Endoceras raymondi* described below. (3) Forms with the cones broadly triangular, with a sharp midventral angle, and terminating in a tube on the dorsal side of the siphuncle. These species are set apart in the new genus *Triendoceras*. (4) Shells with a central tube, but showing a middorsal thickening of the endocone material. The tube is slender, small, but widens to an appreciable cavity in a large apex of the *Nanno* type. These forms are here set apart as the genus *Chazyoceras*.

An additional but undescribed element consists of isolated endosiphuncles slender apically, rapidly expanding adorally, clearly referable to *Cyrtovaginoceras*.

Toufangian

Kobayashi (1934) has described a number of very significant endoceroids from the Toufangian of Manchuria, largely from the Chikunsan shale. They show a general similarity to forms from the Chazyan, but enough differences to be perplexing. *Kotoceras* is so similar in many ways to the Chazyan *Lamottoceras* that in describing the latter genus I seriously considered assigning its species to Kobayashi's genus. Their endosiphuncular features are quite similar; further, *Kotoceras cylindricum* and *Lamottoceras nodosum* show broadly annular siphuncles which are similar to each other and quite different from those of most other endoceroids. However, *Kotoceras* is supposedly holochoanitic, and new material shows that *Vaningenoceras* is not. *Cyrtovaginoceras pacificum* occurs here. Available descriptions and figures are not altogether adequate for the other endoceroids, for descriptions were written before the presence of short necks in endoceroids was recognized as a prevalent condition. There is a suggestion of generalized Endoceratidae, but no evidence of such Proterocameroceratina

with specialized endosiphuncles as are known in the Chazyan of the Champlain Valley.

Orthoceras Limestone

As noted above, there is some difficulty in assigning described species to their proper horizon in the Orthoceras limestone succession, and indeed, some succeeding beds are involved in this same perplexity. However, it is fairly evident that the upper Red and upper Grey horizons contain those endoceroids with very long septal necks which probably influenced Hyatt to ascribe such necks to *Vaginoceras*, and these forms are now the genus *Dideroceras*. Apical ends are clearly of the *Nanno* type. This general part of the column is also probably the source of the original material of Holm's genus *Suecoceras*, in which the camerae extend to the apex around an apical swelling of the siphuncle. Early stages of *Suecoceras* are smaller and more slender than those of *Dideroceras*, The siphuncle wall appears holochoanitic, not macrochoanitic, but further morphological investigation of the genus is needed. Specimens of the aspect of *Dideroceras* show some variation in the position of the tube; it is central in some forms, ventral in others. It is questionable which of these several forms is properly *D. wahlenbergi*. Related forms of *Dideroceras* have been described from the Orthoceras limestone of central China by Yü (1930), which contains a cephalopod fauna allied to that of the upper Orthoceras limestone of the Baltic. *Chisiloceras* Gortani from Chisil Pass in the Karakouram Mountains, is essentially a *Dideroceras* modified by migration of the siphuncle to the center of the shell, a condition not found elsewhere in the Endoceratidae.

Cyrtendoceras is also from the upper part of the Orthoceras limestone, at least in part.

Several considerations suggest that the upper Red Orthoceras limestone may belong in the Whiterock interval, discussed above. The Vaginatenkalk and glaukonitkalk below are Canadian, and both probably late Canadian. The *Platyurus* horizon, low in the Upper Red horizon, contains actinoceroids closely allied to those of the Whiterock of North America. If *Dideroceras* is that low, it is indeed remarkable to find that, as the oldest of the true Endoceratidae, it has the greatest prolongation of septal necks found in the whole of the family.

Although no endoceroids with complex siphuncles have been found in the upper red or upper gray Orthoceras limestone, a rather remarkable form was described by Holm from the *Echinosphaerites* limestone above. This is *Endoceras gladius* Holm (1885). Though Holm's description of this form shows a perception of structure far in advance of his time, there remain some questions which his descriptions and illustrations fail to answer, and without these answers, one cannot say where in the endoceroids this form should be placed. Quite probably it represents a genus as yet unnamed and undescribed. Indeed, his materials suggest differences best explained by regarding his material as containing representatives of two very different species. His pl. 2, fig. 2a,b, shows a siphuncle with the endocone material inflated into a large convex mass on the ventral side similar to that found in the Manchuroceratidae and Emmonsoceratidae. Cones terminate in a flattened tube, from which a pair of blades extend laterally to the wall of the siphuncle. His pl. 3, fig. 1, shows a siphuncle in which the endocone cavity is semicircular, the ventral wall straight and not curved as in the preceding form, while farther apicad the small slightly depressed tube is supported by a single dorsal blade and two ventrolateral ones. Nothing is known of the structure of the siphuncle wall. Both of these forms appear to be more probably members of the Proterocameroceratina than of the Endoceratidae; nothing approaching the degree of complexity shown by these siphuncles is known in the Endoceratina. Admittedly, knowledge of the earlier Ordovician European endoceroids is meagre; further investigations both of morphology and of stratigraphic occurrence are needed.

Mohawkian

No derivatives of the Proterocameroceratina are known in American Mohawkian strata, in which are included the Black River and Trenton intervals. Here endoceroids are often abundant, though many specimens are fragmentary and poorly preserved. However, some generalizations concerning the endoceroids are possible. *Cyclendoceras* makes its first known appear-

ance in the Lowville of northwestern New York, and continues into strata of Chaumont, Rockland and Hull age, the Hull association being known only in Quebec. It then disappears from North American faunas for a time, a phenomenon perhaps to be correlated with the withdrawal of boreal faunas. It reappears though only in the west, in Red River faunas, and a single species is here described from Ordovician shales of Gaspé, of possibly latest Trenton age. *Vaginoceras* is a distincrive genus of the Chaumont, and, indeed, the dominant endoceroid there. It continues into the overlying Paquette Rapids beds of the Ottawa River, but is not recognized from higher strata in eastern sections. Anomalously, a true *Vaginoceras* was figured as such by Troedsson (1926) from the Cape Calhoun beds of northern Greenland. No comparable forms are known in the more southerly faunas of Red River aspect. This *Vaginoceras* is one of several faunal elements in the Cape Calhoun beds which suggest that the Cape Calhoun may include more than one fauna, that with a typical Red River association there has been identified an earlier fauna, possibly more closely allied in time to the underlying Gonioceras Bay limestone. There are species of *Actinoceras* here belonging to species groups elsewhere characteristic of Black River faunas and unknown in Red River associations. The same is true for the several species of *Gonioceras*. Smooth Endoceratidae with simple circular endocones are unknown in the typical Black River, but one such species awaits description from the Chaumont of Quebec, and similar forms occur in the Platteville association of the upper Mississippi valley, where true *Vaginoceras* has not been recognized. It is of interest that *Nanno aulema* Clarke is from this association, while apices of the *Foerstellites* type appear to be characteristic of *Vaginoceras*.

The middle Trenton Sherman Fall limestone contains associations of particular importance. It is quite clearly from the Denmark member that most, and possibly all of Hall's original material of *Endoceras* was derived. The writer had, for some years, accumulated additional material from these beds to be used ultimately in a revision of *E. proteiforme*, for it is quite obvious that the original material contains more than a single species. Thus far the material has proved insufficient to indicate more than general conclusions. Variations in proportions of the gross features of the shell indicate that several species occur in the association. Specimens showing well preserved endosiphuncles commonly exhibit an endosiphocone of depressed section terminating in a tube in the ventral half of the siphuncle as shown here on pl. 60, fig. 6. Foerste (1928) had, however, had refigured and designated as a lectotype of the species a specimen in which the depressed cone terminates in a tube in the dorsal part of the siphuncle. It is the belief of the writer that the two species are distinct, but revision is delayed until still better and more complete specimens can be studied.

It has long been recognized that the Cobourg faunas mark a return of boreal faunal elements into eastern North America, but previously there has been no indication that this situation is reflected by the endoceroids. Clearly, neither the Cobourg of New York and Ontario nor the Tetreauville and Terrebonne faunas of Quebec have yielded anything recalling either *Vaginoceras* or *Cyclendoceras*. Likewise, no recurrence of these Black River types is evident in the Catheys or Cynthiana endoceroids. *Endoceras microlobatum*, the only Terrebonne endoceroid thus far described, appears to be a descendant of the common Sherman Fall types, having depressed elliptical cones terminating in a ventrally located tube. There are, however, in the Terrebonne of Quebec and in the Cynthiana-Catheys associations little known endoceroids in which cones are circular in section and terminate in a centrally located tube. Similar species occur in Red River faunas, but there are similar forms also in the Convington faunas of Cincinnati as well as in the typical Richmond ones above. Interestingly, no *Cyclendoceras* is found in these late Trenton or Upper Ordovician eastern assemblages, the only eastern species in the later Ordovician being *C. clarkei*, already noted, in Gaspé.

Red River Faunas

Recent work indicates that the Red River faunas, which have long appeared in the literature as of Richmond age, are equivalent to the late Trenton Cobourg faunas, in the broad sense, and the early Cincinnatian

Eden beds (Flower, 1956*b*). The endoceroids of the Red River associations, which we find discontinuously preserved from central Texas and New Mexico to Greenland include the following types: (1) typical *Cyclendoceras*, which is, indeed, represented by more recognized species from Red River faunas than from Black River or early Trenton beds. While more information on the internal structures of the Red River species is to be welcomed, a review of the genus suggests that it is a natural one, except for a very few dubious species, and none of these dubious forms occur in Red River associations. (2) smooth endoceroids tentatively retained in *Endoceras*, in which cones are circular and the tube central. Blade structure in these species is not yet evident. (3) rare apical ends in which the apically swollen siphuncle is enclosed dorsally by camerae, the general form type to which the generic name *Cameroceras* has been applied. (4) the anomalous genus *Narthecoceras*, which is here set apart in a family by itself. It is known to range from Greenland to southern Manitoba, but has not as yet been recognized farther south.

Covington and Richmond

Eden and Maysville faunas have yielded endoceroids which are so fragmentary that even after some years of collecting with particular reference to these forms, the present available material is still most inadequate for a proper evaluation of genera and species. It is evident that there are there no annulated shells of the aspect of *Cyclendoceras*, but only a group of large externally smooth shells. Species with circular endocones and a central tube occur, but there are others which depart from this pattern, particularly a group of Eden species in which the cones assume a triangular cross section as in the Chazyan *Triendoceras*. It is, however, suspected that the orientation of the triangle is reversed in the Eden forms, its broad base rather than its narrow apex being ventral. Well preserved apical ends of siphuncles are almost unknown in Covington beds. Curiously, such apical ends are found in the type Richmond, and they run the gamut from *Nanno* through *Cameroceras* to *Foerstellites*. Indeed the genotype of *Foerstellites*, *F. fabrei*, is from the Saluda beds, and is known to belong to a large endoceroid of generalized aspect with circular cones and a central tube. In the upper Mississippi Valley the Stewartville contains a cephalopod fauna with many types of Red River aspect, but the endoceroids there are as yet too poorly known to supply a basis for a significant comparison. The overlying Dubuque has yielded some large endoceroids recently studied by Miller & Kummel (1944), but while general proportions are known, the internal structures have not been closely investigated. The overlying Maquoketa shale has yielded endoceroids, in which there are some generalized smooth endoceroids, some forms which may be true *Cyclendoceras*, and a group of species with very low close annuly which are atypical of *Cyclendoceras*, and rather resemble some endoceroids, known only from portions showing late growth stages, in the Sherman Fall limestone of New York. It is perhaps significant that *Endoceras seticorum* Strand of the upper Ordovician of Oslo appears to have an endosiphuncle of triangular section, terminating ventrally, and is possibly allied to the group of Eden species noted above. With it, however, there is an apparently typical *Cyclendoceras*.

Western Richmond

Richmond beds occur above those with Red River faunas in a broad belt extending from southern New Mexico to the western side of Hudson Bay. Throughout much of this range, dolomitization has destroyed many of the fossils, has obscured original lithic differences between Red River and Richmond sediments, and has resulted in such massive beds that collecting *in situ* is virtually impossible. Richmond beds are sometimes difficult to distinguish faunally and lithologically, but have been recognized in the upper Montoya, upper Fremont, upper Bighorn, while in Manitoba where dolomitization is less advanced the Stony Mountain has long been recognized as distinct from the typical Red River below, and at Hudson Bay the Shamattawa limestone and the underlying Port Nelson have been recognized as distinct. Curiously, while these Richmond faunas above Red River associations have yielded only occasional endoceroids, *Cyclendoceras* is unknown, and

the smooth Endoceratidae are too incompletely known for any very significant analysis of their relationships.

Summary

While endoceroids show some zonation in the Canadian which promises to be of considerable practical value, and Chazyan faunas can be recognized by the association of Proterocameroceratina and Endoceratidae, the endoceroids in succeeding Ordovician faunas appear to be more generalized, and more difficult to use as a basis of faunal analysis. However, some genera, notably *Vaginoceras* and *Cyclendoceras* show some significant features in the distribution of their species. As yet many of the endoceroids from Black River to Richmond strata have been studied only superficially. It is evident that the endosiphuncles may serve as a guide to relationships, and that groups thus defined are probably natural ones and will show significant relationships. However, the information now available is only a beginning, for as yet little attention has been given to variations of internal structure of endoceroids in later Ordovician faunas. Preservation phenomena as well as general neglect of these structures is involved, for not only are the later Ordovician endoceroids found in a fragmentary condition, but for some reason, internal preservation of typical material is rather poor. The endosiphoblades, found so useful in evaluating Canadian and earlier Ordovician endoceroids, are rarely found well preserved in the younger Ordovician species. Quite probably this is because the endosiphuncles thus far found in the younger faunas have been extensively and coarsely recrystallized. It is, however, necessary to emphasize that present results indicate that a closer study of structure of the younger endoceroids from better preserved material will be most rewarding.

STRATIGRAPHIC NOTE

The accompanying diagram (text-fig. 1) of endoceroid phylogeny involves the separation of the Canadian and Ordovician as distinct systems, a course which, aside from its other merits, lends itself remarkably well to the portrayal of cephalopod evolution. This restricted Ordovician is divided into the three old divisions of Chazyan, Mohawkian and Cincinnatian. These divisions are, admittedly, inadequate. The revision of the Chazy-Black River interval by Cooper (1956) appeared too late to be incorporated. Further, while recognition of a Whiterock interval, and a significant interval between the Chazy and Black River are both highly significant, their application to the endoceroids is, for the moment impractical. Almost nothing is known of the Whiterock endoceroids, and of those of the Ashby and Porterfield intervals. Retention of Chazy and Black River seems desirable for the endoceroids, because the best known endoceroids of these intervals are from the type Chazy and Black River sections, while those from other regions are very poorly understood. Likewise, the Red River beds are here indicated as lying athwart the Mohawkian-Cincinnatian boundary, for their equivalence with both Eden and Cobourg, themselves largely equivalents, seems well established. Actually, it will be necessary to either group the Eden with the late Trenton, or, perhaps better, to include the beds now considered late Trenton as part of the early Cincinnatian. The problem will be discussed more fully elsewhere, and the present perplexities may only reflect the fact that there is no good natural tripartate division of the Ordovician possible.

DESCRIPTIONS OF GENERA AND SPECIES

Genus LAMOTTOCERAS Flower, 1955*b*

Lamottoceras ruedemanni and *L. nodosum*, the only previously described species of this genus, are both based upon isolated endosiphuncles, so distinctive that a new genus had to be erected for them. The marginal part of the endocone is sinuous, sloping gently forward from venter to dorsum, but with prominent forward projecting lobes of great prominence on both the middorsal and midventral regions. As noted, the genus appears to be allied to *Kotoceras* Kobayashi, a genus which, according to Kobayashi's descriptions (1934) had holochoanitic septal necks. Further, it was believed at that time on the basis of material not then studied thoroughly, that a specimen referable to *Lamottoceras* showed similar holochoanitic structure. The supposition was wrong. The specimen in question is here described as

Pliendoceras valcourense. It is typical of the Endoceratidae, but differs from *Lamottoceras* in having a large *Nanno* type of apical end, and somewhat different endocone structure. The same association has, however, yielded a septate *Lamottoceras*, *L. franklini* described below, which proves to have very short septal necks atypical of the Proterocameroceratidae. Consistent with this interpretation are the slender nature of the apical part of the siphuncle and the rather complex nature of the endocones. Reexamination of the Asiatic material will be necessary to determine the relationship between *Lamottoceras* and *Kotoceras*. It is possible of course that the genera are unrelated, but this seems unlikely in view of their close similarity, and from their position in beds which, in spite of difficulties in correlation over so large an interval, seem essentially contemporaneous. It may be that *Kotoceras* will prove to be ellipochoanitic on further examination. When it was described most endoceroids were thought to be holochoanitic. It is of course also possible that *Kotoceras* could be one of the rare developments of holochoanitic necks within the Chazyan Proterocameroceratinae, as is *Emmonsoceras*.

LAMOTTOCERAS FRANKLINI Flower, n. sp.
Pl. 59, fig. 4; pl. 60, fig. 5; text-fig. 2C,E,F

Shell rapidly expanding, the dorsum convex, in the early portion, later the shell is a very slender endoceroid with extremely closely spaced transverse septa. The shell is compressed in its present condition, a condition which is largely original, though it may have been augmented very slightly by flattening. The apical part is incomplete. In the adoral 100 mm. of the phragmocone where the shell is slender, the height increases from 28 to 41 mm. The rate of expansion decreases gradually adorally. There is also a portion of the living chamber 30 mm. in length. The measured portion contains 32 camerae, increasing from 2 mm. to 4 mm. in depth. Sutures are straight and transverse adorally, the only region where they can be seen, septa are rather deeply and symmetrically curved, the greatest depth attained midway between dorsum and venter.

The siphuncle wall consists of aneuchoanitic necks and extremely thick connecting rings. Endocone material is present only in the apical part, extending farthest forward to the 45th camera from the living chamber. It is in a region of the shell where the dorsal outline becomes convex and approaches the venter with increasing rapidity. It is worthy of note that there is no indication here of alteration of the gentle contraction of the siphuncle toward an extremely slender apex, a feature of the Proterocameroceratidae, consistent with the extremely short septal necks found in the siphuncle wall. Unfortunately the apex of the shell is lost, and the siphuncle is incomplete, but it is evident that not more than 15 mm. of the apical part of the shell can be missing from the dorsal outline, that the siphuncle is uninflated there, Indeed, the logical reconstruction is that the siphuncle expands from a rather small apical end with moderate rapidity where the shell is quite rapidly expanding, and then both the siphuncle and the shell become essentially tubular.

The pattern of the endocones cannot be determined with certainty. It is evident that the endocone terminates in a tube which is essentially central. Endocone material seems to extend farther forward on the dorsum than on the venter. Further, there is indication of forward projection in a narrow middorsal area, suggesting that this form with short necks has the pattern of *Lamottoceras*, rather than holochoanitic necks as previously suspected (Flower, 1955*b*, p. 815).

EXPLANATION OF PLATE 59

FIGS. *1–3*—*Chazyoceras valcourense* Flower, n. sp. *1*, holotype, lateral view, venter on left, ×1. *2*, Enlargement of dorsal wall of siphuncle from holotype showing holochoanitic necks, ×2.4. 3, paratype, an isolated siphuncle, naturally weathered, lateral view, venter on left, ×1. Both from the Middle Chazy limestone, shore of Lake Champlain at Valcour, N. Y.

4—*Lamottoceras franklini* Flower, n. sp. Enlargement of portion of siphuncle wall, ×7, showing aneuchoanitic necks and short thick rings. Same locality and horizon.

1

2

3

4

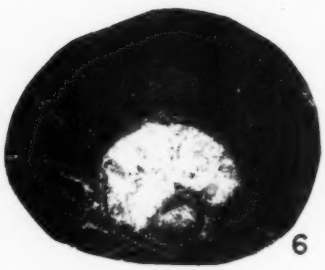
1

2

3

4

5



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Discussion.—The accompanying outline drawing gives a restored concept of this species, showing the proportions of the blunt apex, the restored parts, and the general proportions of the species. Vexingly this species, which proves to have short septal necks, is found in association with some other closely camerated endoceroids in which the necks are holochoanitic or subholochoanitic, and distinction on shell proportions is always extremely difficult in endoceroids. It was on the basis of the associated forms that the statement was made that *Lamottoceras* was probably holochoanitic and a member of the Endoceratidae. From the present evidence, this conclusion was erroneous, and *Lamottoceras* appears to be aneuchoanitic and therefore a member of the Proterocameroceratidae. That *Lamottoceras* is similar to the Asiatic *Kotoceras*, in which holochoanitic necks are reported, adds to the perplexity of the situation. Certainly the present specimen, by its short necks and slender apical part of the siphuncle is one of the Chazyan survivors of the dominantly Canadian Proterocameroceratidae. The perplexity which exists is only one of many indications of the amount of detailed work necessary on endoceroids before their evolution and taxonomy will be really adequately understood.

This species shows, by its siphuncle, a much smaller and much more attenuated apical end than is present in *Lamottoceras ruedemanni*. *L. nodosum* shows wide low annuli on the siphuncle which are definitely absent in the present species. Other described endoceroids of the Chazyan are not closely comparable, being much more sparsely supplied with septa. Quite probably this species is one of several which have been formerly embraced under the identification of *Cameroceras tenuiseptum* (see Ruedemann, 1906, Flower, 1955*b*) but none of the endoceroids figured by Ruedemann are conspecific with the present form. The closest one is shown in Ruedemann's pl. 6, fig. 2, but this is a shell which while closely septate and from the same locality as our present type, shows a much larger size than this species probably attained and, more important, an appreciably greater rate of expansion of the shell.

Holotype.—Collection of the writer.

Occurrence.—From B3 or 4 of Ruedemann's section (1906, p. 398), on the shore of Lake Champlain, at Valcour, N. Y.

VANINGENOCERAS Flower, n. gen.

Genotype.—*Vaningenoceras styliforme*, n. sp.

This genus is based upon endosiphuncles. The fact that all known Chazyan Endoceratidae have an apex of the Nanno type, and that this form has a siphuncle tapering gently to an extremely small diameter, suggests that it is one of the Chazyan survivors of the Proterocameroceratidae. The siphuncle is essentially circular in cross section, without clear septal markings on which orientation can be established with certainty. Endocones are long, straight in the young, becoming sinuate in longitudinal section in the latest observed growth stages. The cones terminate in a central tube. In cross section the tube is flattened ventrally, rounded dorsally, subangular ventrolaterally. Three obscure blades develop, one

EXPLANATION OF PLATE 60

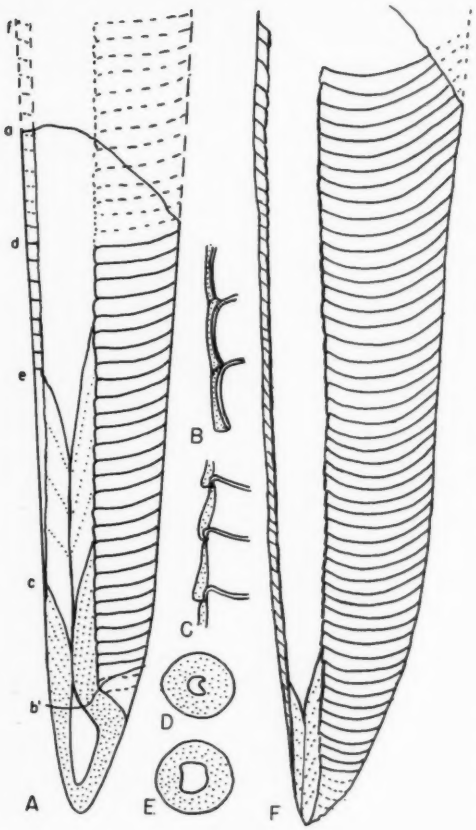
FIG. *1*—*Triendoceras orthoseptatum* Flower, n. sp. Holotype, ×1, a natural weathered section, viewed from dorsum. Crown Point limestone, Chazyan, from the Lake Champlain shore at Valcour, N. Y.

2—*Triendoceras montrealense* Flower, n. sp. Holotype, ventral view, ×1. From the Chazy limestone of Montreal, Quebec.

3–4—*Endoceras raymondi* Flower, n. sp. 3, lateral view of sectioned holotype, ×1, venter on right, *4*, enlargement of part of dorsal wall of siphuncle from anterior end of the same specimen, ×7, showing holochoanitic necks. Same locality and horizon as fig. 1.

5—*Lamottoceras franklini* Flower, n. sp. Holotype, ×1, lateral view of weathered surface, partially exposing the siphuncle on the ventral (left) side.

6—*Endoceras proteiforme* Hall. Apical view of a form with the cones elliptical, depressed, and terminating on the ventral half of the siphuncle. Denmark member, Sherman Fall limestone, from Trenton Falls, N. Y.



TEXT-FIG. 2

A,B,D—Chazyoceras valcourense. *A*, a vertical longitudinal section, restored, based upon the holotype and paratype. The holotype, which extends from *a* to *b*, has the anterior endocones at *c*, and base of the living chamber at *d*. The paratype shows the anterior endocones at *e*, and extends to the apex. Its phragmocone extended anteriorly to *f*. *B*, enlargement of a small portion of the dorsal wall of the siphuncle, from section shown in pl. 59, fig. 4. *D*, Cross section of siphuncle from near base of holotype, showing dorsal emargination of endosiphocone at left.

C,E,F—Lamottoceras franklini. *C*, portion of dorsal wall of siphuncle of holotype. *E*, cross section of siphuncle through endosiphocone, venter at left. *F*, restoration of holotype, vertical longitudinal section, venter at left. *A* and *F* are two-thirds natural size.

midventral, and two dorsolateral. The genotype shows the endosiphocone terminating in a gently conical slender cavity seemingly without prominent walls, which is extremely short. Beyond it is a tube, roughly semicircular in cross section. At regular and rather widely spaced intervals this tube is blocked by broad carbonaceous obstructions, so extensive that they are clearly not true diaphragms, though probably homologous with them in origin.

Discussion.—The above generic description is based essentially on the genotype, described below. *V. indomitum* is a much larger species, and one which fails to develop the sinuate profile of the anterior endocones. It may well be that in spite of its large size, the anterior end of this specimen has not attained maturity. The specimen which Neumann (1951, pl. 9, fig. 9), figured as a *Beatricea* from the Linconshire limestone of Virginia, seems to be congeneric also; certainly it is an endoceroid siphuncle very similar to *V. indomitum* in cross section of the center, as well as in general conformation of the cones.

VANINGENOCERAS STYLIFORME Flower, n. sp.

Pl. 61, figs. 1–6

This species is based upon an endosiphuncle which is slender, straight, so devoid of septal markings that correct orientation is still uncertain. The siphuncle as now extant is 190 mm. long, was slightly depressed, but nearly circular in cross section, and expands from 9 mm. at the apical end to 17 mm. in the length of 190 mm. There was originally a small apical portion, uniform in expansion with the rest of this siphuncle which was lost. Endocones are long, slender, numerous. The natural section from which the specimen was first known suggested an extremely ordinary siphuncle of the Endoceratidae, a condition belied by the extremely slender apex. The last endocones become sinuate as seen in longitudinal section, concave near their tips, convex in the middle, concave again as the tip of the cone is approached. The anterior endosiphocone gives way to a central cavity 10 mm. long, 3 mm. wide anteriorly, contracting apically to 1 mm. Along the wall of this cavity, which is not sharply demarcated, can be seen the tips of numerous endocones, spaced 6 in a length of 5 mm. Farther apicad this cavity, which fits well Ruedemann's concept of an endosipho-

coleon, gives way to a slender tube, flattened on one side, the assumed venter, rounded on the other. This tube is faintly expanded and contracted at rhythmic and rather distant intervals. It is filled with calcite, and at the widened points, appears to be blocked by black carbonaceous material.

Cross sections made at several points show, through variations resulting from replacement, a rather characteristic pattern. The endocones in cross section are extended out toward the siphuncle wall in one point, clearly ventro-lateral if the flattened side of the tube is taken as ventral. In the restoration, it is necessarily assumed that this continues onto the opposite ventrolateral side, an assumption supported by cross sections showing this side near the tip of the cones. Three blades are present, though faint and variably developed. One is ventral, two others are dorsolateral.

Discussion.—This small siphuncle is distinguishable by the characters of the genus, from nearly all other forms. When first found, it was a seemlingly nondescript and quite obviously typical endoceroid, but the cross section of the cones, position of the blades, sinuate profile of the anterior cones and the small slender apex supply highly distinctive features. Without the siphuncle wall the position of the genus in the Endoceratidae or elsewhere would be seemingly impossible to determine. However, that all Chazyan Endoceratidae thus far known have apices of the *Nanno* type, and that no true Endoceratidae are known to have small slender initial parts of siphuncles, makes reference to the Proterocameroceratidae a safe inference.

Holotype.—Collection of the writer.

Occurrence.—From the Middle Chazyan Crown Point limestone, from the higher layers exposed beneath the New York-Vermont Bridge, at Crown Point, New York. Collected in 1933.

VANINGENOCERAS INDOMITUM Flower, n. sp.

Pl. 61, figs. 7–12

This is based upon a large somewhat distorted siphuncle, a portion 220 mm. long, expanding from 25 to 40 mm. in mean diameter. Surface of siphuncle not exposed The anterior end includes nearly all of the endosiphocone, which is subangular on one side, evidently involving some distortion. The tip of the cone is attained in 120 mm. Near its tip the section becomes subtriangular, the venter flattened as in the preceding species, the dorsal region very narrowly rounded. In cross section cones are clear but blades are obscure. There appear to be two dorsolateral blades and a middorsal one which may be adventitious; the ventral blade is not evident. A longitudinal section shows the base of the cone, which is preserved for only a short distance. It is evident that as in the preceding species, the tube is obstructed by organic material, which here has the form of an extremely thick diaphragm, and is concave on the anterior side. The tube appears to be slightly swollen at rather widely spaced intervals.

The apical part of the siphuncle is badly recrystallized, but there shows evidence of a pair of ventrolateral blades.

Discussion.—This large siphuncle is of interest in that the aspect in cross section is very similar to that of an endoceroid siphuncle from the Linconshire limestone of Virginia (Neumann, 1951, pl. 9, fig. 9, figured as a *Beatricea*).

Though cross section of the cones is here somewhat more triangular and the anterior cones fail to develop the sinuate pattern found in the late stages of the preceding form, the two are allied in the diaphragms crossing the tube, and are regarded as congeneric.

Holotype.—Collection of the writer.

Occurrence.—From the bay northeast of Cystid Point, on the southeast side of Valcour Island, from beds regarded as of Upper Chazyan age.

GENERIC DIFFERENTIATION WITHIN THE ENDOCERATIDAE

It is largely due to the limitations of typical material that the recognition of generic groups in the Endoceratidae is most uneven and inadequate. Shells are generalized in gross features.

Only one genus, *Cyclendoceras*, differs from others in features of the shell wall. No genera have been differentiated on the basis of variations in the suture pattern or cross section. Two genera, *Dideroceras* and *Chisilo-*

ceras, are set apart from all other Endoceratidae by the development of very long, macrochoanitic septal necks. They are confined to the faunal realm of the Orthoceras limestone, being known, anomalously, from northern Europe, central China and southeastern Asia.

It is rather exasperating that the remainder of the Endoceratidae are difficult to separate into adequate genera, and even species. Such separation is inhibited by the fragmentary nature of materials, modification of proportions by distortion, difficulty of correlating fragments showing noncomparable shell parts, and uncertainty as to the extent of variation in proportions within a species. It is, however, evident that if any separation is to be made within the prolific stock of the Endoceratidae, it must involve differences shown by the endosiphuncle, for there is here wide structural variation which contrasts sharply with the generalized and uniform aspect of the gross shell features.

While theoretically *Cyclendoceras* is suspect as a natural genus, for annuli may have developed more than once in the Endoceratidae, a review of the species does suggest that the genus is a closely knit one and probably a natural group. *Vaginoceras*, a long established generic name, is found to be a genus confined to Black River faunas with endocones compressed and cuneate in cross section, a central tube, and dorsal and ventral blades which are usually prominent and well preserved. If, however, one is to distinguish *Vaginoceras* from features of the endosiphuncle, it follows that other generic groups may be based upon different patterns formed in the same structure. Any such genera that are recognized will, automatically restrict the scope of the genus *Endoceras*, in which all of these generalized endoceroids have been placed. In the process, one must take into account the features of the endosiphuncle of *Endoceras proteiforme*, and, unfortunately, present material is not completely adequate for the solution of problems relating to this species. The type material of *E. proteiforme* is from the Denmark member of the Sherman Fall limestone, Middle Trenton. The writer has collected extensively from this horizon in the hope of obtaining material adequate to determine, first, the species in this association, for there are obviously several species there, and second, to determine the endosiphuncular structure of what should properly be considered *E. proteiforme*. Unfortunately, much of the material shows rather extensive recrystallization of the endocones, a process which may obliterate the margins between individual endocone units, and the blades as well. The best material has shown the endosiphocone to be depressed elliptical in cross section, and terminating in a tube located in the ventral half of the siphuncle. Such material, shown here on pl. 60, fig. 6, I had previously taken as typical of *Endoceras proteiforme*. In doing so, I had, however, overlooked the fact that Foerste (1924) had designated as the lectotype of *E. proteiforme* a specimen which has endocones of depressed elliptical cross section, but which terminate in a tube located in the dorsal, and not the ventral part of the siphuncle. Actually, such forms are extremely rare in the Denmark member of the Sherman Fall limestone at Trenton Falls, while the form with ventrally terminating cones is common. Further, related species with ventrally terminating cones are known in other parts of the Ordovician, but as yet I have encountered no other forms in which the cones terminate dorsally. Restriction of *Endoceras* on this basis would leave in it only one species known from its type and possibly represented by a few other specimens. Such restriction of *Endoceras* is obviously impractical though it seems inevitable that the species *E. proteiforme* must be restricted to such forms.

The alternative course, to treat *Endoceras* broadly, ignoring the variations in the structure of the endosiphuncle, would leave the Endoceratidae containing the annulated *Cyclendoceras*, the two macrochoanitic genera *Dideroceras* and *Chisiloceras*, but retaining all other species in *Endoceras*. Plainly, one cannot differentiate *Vaginoceras* on the features of the endosiphuncle and leave all other endosiphuncular patterns in the single genus *Endoceras*.

The following divisions are suggested:

I. Typical *Endoceras*.—Endocones depressed, terminating usually ventrally but also occasionally dorsally. Blades poorly known, siphuncle apex of the *Cameroceras* type.

II. Typical *Vaginoceras*.—Compressed cu-

neate cones, angled ventrally rounded dorsally, terminating in a central tube with one dorsal and one ventral blade. Apex apparently of the *Cameroceras* type.

III. *Chazyoceras*, n. gen.—Cones extend farther forward dorsally than ventrally, dorsal part of endocone thickened so that the resulting speiss is slightly emarginate there: tube central, enlarging to a cavity of appreciable size in the large *Nanno* type of apex.

IV. *Triendoceras*, n. gen.—Endocones have the cross section of an isosceles triangle, the sharp apex on the midventral side; dorsolateral angles may be more rounded. Blades and apex of siphuncle as yet unknown.

Other possible generic groups have been noted, but their publication is delayed pending further study, largely because of the evident need of further study of species within them, prior to the selection of genotypes. Already noted in the discussion are forms typified by *Vaginoceras oppletum* Ruedemann, with cones narrowed ventrally, rounded dorsally, and with more than the two blades found in typical *Vaginoceras*, and forms with perfectly circular endocones and a central tube which are the common endoceroids in Red River and Richmond species.

From our present evidence, the recognition of genera based upon the form of the apical end of the siphuncle alone, is impractical. The *Nanno* type of apex is believed to be the primitive type in the Endoceratidae. It is the only type found associated with Chazyan Endoceratidae, but there it pertains to species representing several different genera. It is found in the group of *Vaginoceras oppletum*, and *Chazyoceras*, but it is also found in *Dideroceras* of the possibly slightly older Orthoceras limestone faunas. *N. aulena* of the Platteville is not yet identified with large adult endoceroid shells; it may prove that *Nanno*, as based upon this typical material is based upon a series of fragments from immature shells; it is, however not impossible that *N. aulema* is an endoceroid which attained maturity when the phragmocone was extremely short and endocones were scarcely developed beyond a most rudimentary stage. Certainly most of the specimens of *N. aulema* have endocones lacking or confined to the very tip of the siphuncle cavity. There are also large undescribed Cincinnatian specimens of the *Nanno* type.

Typical *Suecoceras* is known only from the Orthoceras limestone faunas. As yet the siphuncle wall and the pattern of the endosiphuncle in typical species are inadequately known. However, the *Cameroceras* type of apex is very similar to that of *Suecoceras*, differing mainly in its larger size and the more annular appearance of the surface. Such apices probably pertain to typical *Vaginoceras*, for they are associated with *Vaginoceras* and no other endoceroid in the faunas of the Paquette Rapids beds of the Ottawa River. *Cameroceras* is again the apical end of typical *Endoceras* in the middle Trenton. In Red River faunas it is found in association with endoceroids with simple circular cones. It persists into the typical Richmond. The slender apex of the *Foerstellites* type is typically developed in the Richmond of the Cincinnati region; as yet ends of this type have not been found elsewhere. Clearly, it is associated with species with circular cones which, from adult stages, show no important difference from those which have a Cameroceras type of apex. It appears probable that the reduction of the *Nanno* type of apex to the *Suecoceras* and *Cameroceras* types, and ultimately to the *Foerstellites* type, is a tachygenetic process which took place in several lines of descent within the Endoceratidae. Clearly, groupings made on the form of the apical part of the siphuncle have little faunal or stratigraphic significance. Rather, forms of the *Cameroceras* and *Foerstellites* type are developed independently in several generic lines stemming from Chazyan endoceroids of the *Nanno* type, in which already several different genetic lines can be differentiated by specializations of the endosiphuncular pattern.

Endoceras Hall

It is unnecessary to repeat here the previous discussion of this genus (Flower, 1955*a*), save to note that as indicated in the above discussion, restriction of the scope of *Endoceras* is initiated here, and will doubtless be carried farther in later works. The two new species described below are notable in combining the generalized features of the Endoceratidae with endocones which are elliptical and depressed in cross section, and

terminate in tubes located in the ventral half of the siphuncle. One, *E. raymondi*, indicates the development of this type of endosiphuncle already in Chazyan time. Its apex is unknown. One cannot but wonder whether, as in other Chazyan Endoceratidae, the apex is of the *Nanno* type. *E. microlobatum* of the late Trenton Terrebonne fauna of Quebec, has a similar endosiphuncle and an apex of the *Cameroceras* type. It is plainly a derivative of the typical middle Trenton group of species of *Endoceras*.

ENDOCERAS RAYMONDI Flower, n. sp.
Pl. 60, fig. 3

This is a small closely septate endoceroid. Cross section not fully observed, believed to be slightly wider than high. Shell expands only very gradually vertically, increasing from 32 to 34 mm. in a length of 80 mm. on the type. The siphuncle is narrowly separated from the venter in the known portion, circular in section, about one-third the shell height in diameter. Septa very closely spaced, between 4 and 5 mm. apart throughout the length of the specimen, rather strongly curved between the siphuncle and the dorsum, in a distance of 20 mm. the septa are 8 mm. deep in curvature, and meet the dorsal wall only slightly orad of their contact with the dorsal wall of the siphuncle. The endosiphuncle is composed of cones slightly sinuate on their dorsal side, nearly straight ventrally and much more steeply inclined there than on the dorsum. The cone terminates close to the venter, being 3 mm. from it and 10 mm. from the dorsum where it is most clearly shown at the anterior end of the holotype. The siphuncle wall is composed of septal necks, faintly sinuate in vertical section on the dorsal side where they are best seen, the inner outline of the siphuncle smoothed by rather thick rings.

Discussion.—This species is a deceptive one in its gross features, being a small closely septate shell more similar to associated Proterocameroceratidae than to the Endoceratidae. However, the nature of the siphuncle wall shows its affinities to the Endoceratidae, and the species is one of particular interest because it establishes the presence of a form in the Chazyan which has the depressed elliptical cones terminating in a ventral tube, as in the typical middle Trenton group of species. The siphuncle wall is quite different from that of the associated *Chazyoceras valcourense;* in that species the long necks form siphuncle segments concave throughout the length of each one; in *E. raymondi* the siphuncle segment is slightly concave at its anterior end, slightly convex at its apical end. *Chazyoceras valcourense* of the same association is distinguishable by the larger siphuncle, the different endocone pattern, and septa which are much less curved, as seen in vertical section, between the siphuncle and the dorsum, each septum joining the shell wall well orad of its juncture with the siphuncle.

The holotype fails to exhibit cross section or sutures. Topotype material, though too unprepossessing and fragmentary to merit figuring, suggests that the sutures were straight and transverse, the cross section subcircular, perhaps very slightly depressed.

Holotype.—Collection of the writer.

Occurrence.—From the middle Chazyan, B2 or 3 of Ruedemann (1906), on the shore of Lake Champlain at Day Point, near Valcour, New York.

ENDOCERAS MICROLOBATUM Flower, n. sp.
Pl. 62, figs. 5–7

The holotype is a shell 115 mm. long, expanding laterally from 47 mm. to an estimated 64 mm. A break near the middle shows a width of 57 mm. and a height of 50 mm., the sides broadly rounded, the venter only faintly more flattened than the dorsum, and both quite well arched. The siphuncle here is 27 mm. wide and 23 mm. high. The exposed ventral surface shows eighteen camerae, increasing in length from 7 to 8 mm. adorally. Sutures are straight and transverse dorsally and laterally, but are modified by a small and shallow but nevertheless conspicuous midventral lobe, more strongly developed in early than in the latest growth stages of the species.

The apical half of the specimen was sectioned vertically, and though the dorsal side of the shell is incomplete, it is evident that the specimen retains the tip of the siphuncle. The siphuncle wall is holochoanitic throughout, and typical of the Endoceratidae. In ventral profile both the shell and the siphuncle wall are very faintly convex on the venter over the apical 30 mm., beyond which both become straight. The dorsal side of the siphuncle is greatly expanded in the

same length, after which it also becomes straight, and the siphuncle expands only gently orad from there on. In the basal 30 mm. the siphuncle expands from a height of 9 mm. to one of 22 mm. In this length are seen first, two long basal camerae 9 mm. in length, two succeeding camerae abbreviated to 5 mm. after which there are normal ephebic camerae, increasing gradually from 7 mm., to 8 mm. in the length of the section, which shows six segments of the siphuncle on its dorsal side in the length of 42 mm. In the section, not only is the dorsal wall lost, but most of the free parts of the septa dorsad of the siphuncle have been destroyed. Evidently the apical end of the siphuncle expanded rapidly, and then assumed a tubular form. It lacks the faint swelling prior to the development of the ephebic gently expanding portion, and is thus not typical of *Cameroceras*. Rather the lack of such swelling would place this apical end in *Foerstellites* Kobayashi. The endocone, clearly seen in section, is typical of *Endoceras*, being subcircular in section, and terminating in a tube which is close to the ventral wall of the siphuncle. In the section, one endocone is clearly outlined, Outside of it is very coarse calcite, evidently a replacement phenomenon. Matrix has penetrated the apical part of the siphuncle which is not quite complete. Its pattern is puzzling, but it may well represent penetration of matrix into a part of the shell removed by solution, possibly even during the life of the animal, but certainly prior to burial of the shell.

Discussion.—Though the present specimen, which is unfortunately unique, shows nothing of the size of the mature shell, it supplies in the low ventral lobe a feature by which the species can be readily recognized. Indeed, the feature is distinctive enough, among so many nondescript endoceroids, that one is tempted, though unwisely, to use the presence of this lobe as an excuse for the erection of a distinct genus. Curiously, the holotype of *E. clarkei* Miller & Furnish (1944, pl. 1, figs. 1,2), of the Dubuque beds of Iowa, shows even more prominent lobes combined with an annulate shell surface, but fragments representing later growth stages and failing to show such lobes have been included in the species. The ventral termination of the endocone is typical of the middle Trenton species which dominate the Denmark member of the Sherman Fall limestone and suggests that *E. microlobatum* is a survival of this stock, rather than one of several introduced boreal migrants. The early portion of the siphuncle here seems intermediate between the *Cameroceras* type and the *Foerstellites* type, being less swollen than specimens figured as *Cameroceras trentonense*, and less slender than typical *Foerstellites*. As previously noted (Flower, 1955*a*) specimens formerly identified as *Cameroceras trentonense* represent early portions of several species of *Endoceras*, and pretty certainly, one of them is *E. proteiforme*. There is no reason on the other hand to believe this species to be closely related with *Foerstellites faberi*, of the Saluda beds of the Cincinnati region. New material shows that this species, formerly known only from an early portion of the shell, is quite a large endoceroid, and one with circular cones terminating in a centrally located tube.

It therefore seems that *E. microlobatum* is definitely allied to the species group of *E. proteiforme*, and is thus far the only such species known from beds younger than the middle Trenton.

The species was probably actually quite a large one. The apex of the shell enlarges rapidly to a considerably larger diameter than does that of *Endoceras proteiforme*, and this fact is an indication, though not an infallible one, of large shell size. Endocone material is present to the anterior end of the type, though there is shown only the thin anterior end of the endosiphocone. This point is about 5″ from the apex of the shell. Analogy suggests that there was probably an anterior portion of phragmocone of at least 10″ more, the siphuncle of which lacked endocone material, and a living chamber of at least an additional 5″.

Holotype.—Collection of Dr. G. Winston Sinclair, Ottawa.

Occurrence.—Terrebonne limestone, upper Trenton, from Isle Jesus, Montreal, Quebec.

CHAZYOCERAS Flower, n. gen.

Genotype.—Chazyoceras valcourense Flower.

Endoceratidae, generalized externally, straight, slender, with close straight transverse sutures. Section slightly depressed, siphuncle ventral, its wall holochoanitic, its

apex of the *Nanno* type. Endocones extend farther forward dorsally than ventrally; a convex thickening of the material appears dorsally near the tip of the endosiphocone. Tube central, widening even in adult shells, to a cavity of appreciable size in the inflated apical part of the siphuncle.

CHAZYOCERAS VALCOURENSE Flower, n. sp.
Pl. 59, figs. 1–3; text-figs. 2A,B,D

The holotype is a portion of a phragmocone 230 mm. in length, flattened laterally by pressure, moderately expanding vertically. Sutures are straight and transverse, septa very closely spaced. The siphuncle is rather large, its height in section more than one third and slightly less than one half that of the whole shell, but apically it is expanded, of the *Nanno* type, and fills the blunt apex of the shell. The basal 35 mm. of the holotype, showing part of the *Nanno* stage, are extremely incomplete and are not included in our photographs. In the adoral 150 mm. the shell expands from 40 mm. in height and 27 mm. in width (probably originally 30 mm., prior to weathering) to a height of 55 mm. and a width of 30 mm. (probably reduced from 35 mm. by weathering). The siphuncle increases in height from 15 to 22 mm. in the length of the phragmocone. Camerae increase in length from 5 to 7 mm. in the length of the type. The siphuncle wall shows thin septal necks, holochoanitic, forming faintly concave siphuncle segments. Within the necks a series of rings, each thicker at its extremes than in the middle, tend to produce a smoother outline of the internal cavity of the siphuncle. Differentiation of material at the tip of the connecting ring represents the eyelet. The anterior 150 mm. of the siphuncle is devoid of endocones. The cone extends farther forward dorsally than ventrally, is altogether rather short, 25 mm. ventrally, 45 mm. dorsally, and terminates in a central tube. Near the apex of the endosiphocone cavity, a cross section shows the cavity to be concave dorsally, this part set off sharply from the remainder of the outline, which is circular. The apical unfigured fragment shows the dorsal wall of the siphuncle expanding apically, as the *Nanno* stage is approached; at the same time, there is indication of convexity of the dorsal wall of the shell.

The paratype, an isolated siphuncle, is from the same bed as the holotype. The specimen was weathered naturally, and is a longitudinal section, though one weathered slightly beyond the median plane. The *Nanno* stage attains a height of the siphuncle of 20 mm., 40 mm. from the apex, then decreasing to 15 mm. in height in the next 7 mm. From there the siphuncle increases in height gently orad, attaining a height of 18 mm. in the next 100 mm. That these proportions are considerably less than those indicated in the holotype is natural, for the specimen is weathered beyond its center, and something less than the maximum height is therefore exhibited. Several cross sections were made, but they fail to show much of the endocone structure of the paratype. There is evident a cavity of appreciable size, in the *Nanno* stage, which narrows

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EXPLANATION OF PLATE 61

FIGS. *1–6*—*Vaningenoceras styliforme* Flower, n. sp. Holotype. *1*, longitudinal section of anterior end of holotype, ×2, penetrating endosiphotube, which contains distantly spaced carbonaceous obstructions. *2*, cross section at base of fig. 1, showing numerous cones in section, and centrally, three blades. 3, cross section 8 mm apicad of fig. 2; showing triangular tube, cones obscured by replacement. *4* cross section 1 mm. apicad of fig. 3, showing cones largely obscured but blades clear. *5*, cross section 12 mm farther apicad, replacement has obscured blades and all but a few of the cone margins. *2–5* are ×3½. *6*, apical part of holotype, overlapping fig. 1, ×1. From the Crown Point limestone, Crown Point, New York.

7–11—*Vaningenoceras styliforme* Flower, n. sp. Sections of holotype, ×1; *7*, near anterior end of endosiphocone, somewhat distorted; *8*, near middle of endosiphocone; *9*, near apex of endosiphocone; *10*, section at anterior end of endosiphotube, showing cross section of cones, triangular tube, and traces of blades; *11*, section from near apical end, showing tube flattened and dorsolateral blades only preserved. *12*, longitudinal section showing extreme tip of endosiphocone. From the Valcour limestone, from the bay norwest of Cystid Point, Valcour Island, N. Y.

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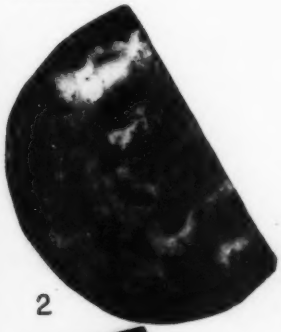
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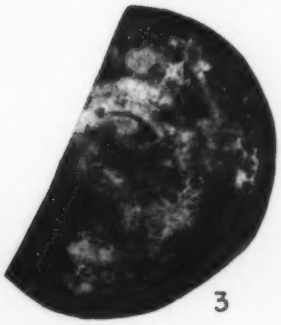
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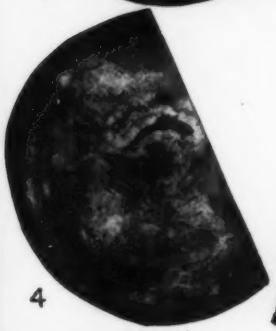
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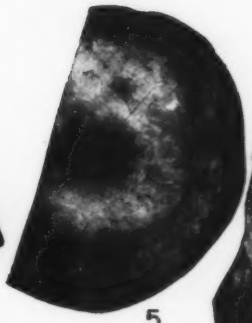
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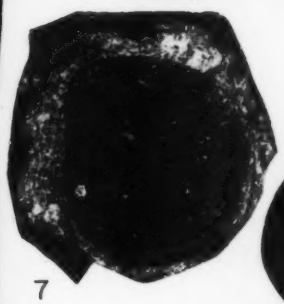
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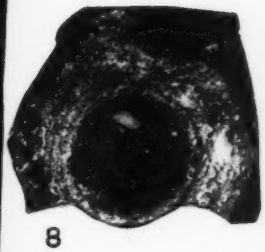
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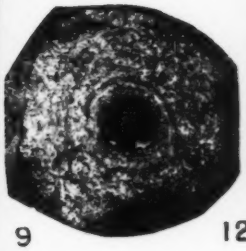
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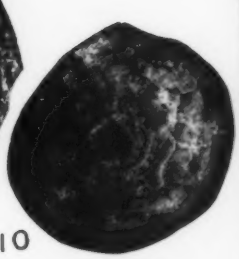
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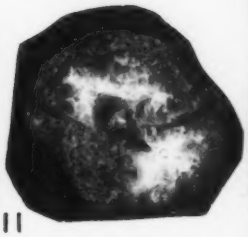
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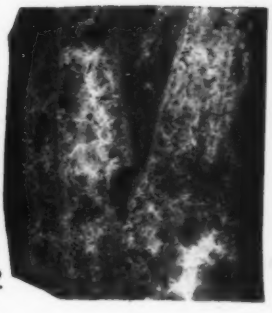
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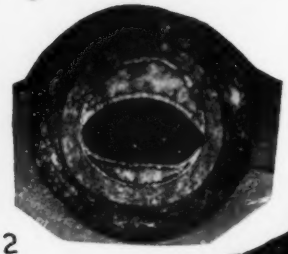

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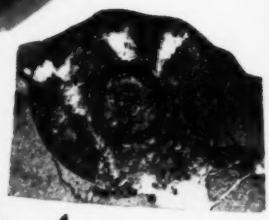

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to a tube extending over a length of 100 mm. before widening into the endosiphocone at the anterior end of the specimen.

Discussion.—The characters of the genus will serve to distinguish this species at present, for no congeneric forms are yet known. The large siphuncle, close septa and sutures, the slight curvature of the septa between the dorsum and the siphuncle, are useful features distinguishing this form associated Chazyman endoceroids of similar proportions. Of previously described Chazyan endoceroids, *Endoceras* (?) *hudsoni* has an even larger siphuncle, though it is somewhat similar in the close spacing of the camerae. Also, its septa are more strongly curved within the shell. *Endoceras* (?) *magister* has very widely spaced camerae and is not closely comparable. Neither of these two species is well enough known to permit a close evaluation of its position in the Endoceratida.

The holotype of *C. valcourense* is flattened laterally. Study of the septa indicates that flattening has crushed the lateral sides together without increasing the original shell height or the rate of expansion in the vertical plane of the shell.

Holotype and paratype.—Collection of the writer.

Occurrence.—From the middle Chazyan, from beds B3 or 4 of Ruedemann's (1906) section, on the shore of Lake Champlain, at Valcour, New York.

TRIENDOCERAS Flower, n. gen.
Genotype.—Triendoceras montrealense Flower, n. sp.

Shells are smooth externally, often large, and with straight transverse sutures. The section is slightly depressed, the siphuncle is close to the venter, its wall structure typical of the Endoceratidae. The distinctive feature of the genus is found in the pattern of the endocones which are triangular in section, the apex of the isosceles triangle directed ventrally, and the termination of the endocones being close to the dorsum, not to the venter. The nature of the apex of the siphuncle is unknown.

Discussion.—Though at the present time only two Chazyan species are assigned to this genus, it is believed to be much more widespread. Siphuncles showing endocones strongly triangular in section are common in the lower part of the Cincinnatian, being prevalent in the upper Eden, and possibly continuing on into the Mount Hope beds. Though such forms are not uncommon, they are known almost entirely from the "speiss," the mud filling of the endosiphocone and their description has been withheld for some years in the hope of obtaining more complete material. It is significant to note them here, as giving an indication of probable extension of the genus into the Covington.

TRIENDOCERAS MONTREALENSE
Flower, n. sp.
Pl. 60, fig. 2

The holotype is a part of an ephebic phragmocone, slender, broadly depressed on cross section. The fragment 110 mm. long expands laterally from 48 to 59 mm. in a length of 90 mm., or a rate of 1.2 mm. in 10 mm. The venter is broadly rounded, without conspicuous midventral flattening. The missing dorsum makes impossible accurate recording of height-width ratios, but clearly the height was only slightly more than two thirds the width. The type retains 33 camerae in its length; they are only 4 mm.

EXPLANATION OF PLATE 62

FIGS. *1–4—Cyclendoceras clarki* Flower, n. sp. Holotype. *1*, ventral view, showing siphuncle and portions of shell wall, ×¾. *2*, cross section at break near anterior end showing elliptical cones superimposed within circular ones. 3, longitudinal vertical section, between 2 and 3, showing unconformity between early and late cones, also portions of siphuncle wall. *4*, cross section at apical end of fig. 3, showing only faintly compressed cones, centrally terminating. Figs. 2–4 are ×1. From Ordovician shales, Anse Pleureuse Cove, north shore Gaspé peninsula.

5–7—Endoceras microlobatum Flower, n. sp. *5*, ventral view of holotype ×¾. *6–7*, opposing sides through apical portion of type, ×1.4, showing holochoanitic necks, ventrally terminating cones, and most of the apical portion of siphuncle of the *Cameroceras* type. Terrebonne beds, Isle St. Jean or Isle Jesus, Montreal, Quebec.

in length, a feature uniform throughout the length of the specimen. The siphuncle is unusually large in diameter, 14 mm. high and 18 mm. wide near the base, expanding to 20 mm. high and 28 mm. wide adorally. It is essentially in contact with the venter. Ventrally, septal markings slope forward to a midventral line forming a conspicuous chevron-like pattern. In the apical part of the specimen the internal mold of the endosiphocone is exhibited. It is short, between 40 and 45 mm. in length when restored to completion. In cross section it has the form of an isosceles triangle, with the broad, slightly convex base close to the dorsal wall, the apex moving progressively farther from the venter, as it is traced toward the tip of the endocone. The resultant tube at the apex of the cone, clearly lay quite close to the dorsal wall. Endocone material is replaced, and there is no evidence of the pattern of the blades.

Discussion.—The species is a distinctive one in the broad cross section, well-arched venter in cross section, the large diameter of the siphuncle and the extremely closely spaced septa.

Holotype.—Collection of Dr. G. Winston Sinclair, Ottawa.

Occurrence.—Chazyan, from quarries on the outskirts of Montreal, Quebec.

TRIENDOCERAS ORTHOSEPTATUM
Flower, n. sp.
Pl. 60, fig. 1.

This species has the essential siphuncular features of the preceding one, but the siphuncle is much smaller in proportion, the septa are more distant, and in the horizontal plane of the siphuncle the septa pass from the shell wall apically to the siphuncle, and are essentially straight instead of being broadly and gently curved. The type retains a part of a phragmocone increasing in width from 36 to 40 mm. in a length of 60 mm. The fourteen camerae are subequal in length, averaging 5 mm. Obliquity is such that in the horizontal plane of the siphuncle, a transverse line will cut nearly two complete camerae. The siphuncle, small in proportion, is 11 mm. wide basally, where the shell is 33 mm. in width. Its slender aspect in the figure is largely original, but has been accentuated by weathering. In all gross aspects, the shell is an extremely generalized one. The holotype preserves a part of the siphuncle showing the anterior part of the endosiphuncle.

Holotype.—Collection of the writer.

Occurrence.—From the middle Chazyan, from the section exposed at the shore at Valcour, New York, along Lake Champlain.

CYCLENDOCERAS Grabau & Shimer
Gentotype.—Endoceras annulatum Hall.

Cyclendoceras was first differentiated from *Endoceras* on the basis of the annulated rather than the smooth exterior of the shell. At that time the complexity of the Endoceratida was not suspected. Theoretically, annuli in themselves may be expected to be as poor an indication of phyletic unity in the Endoceratida as they have been found to be in the Michelinoceratida (Flower, 1943). One may expect that under its original definition, *Cyclendoceras* embraces several real genera of the Endoceratida of independent derivation. Such shells are to be expected in the Proterocameroceratidae as well as in the Endoceratidae. Fortunately, annulated shells of the Proterocameroceratidae have largely escaped description until very recently, and Teichert and Glenister (1954) have erected the genus *Anthoceras* for the first such species to be recognized. The species which have been assigned to *Cyclendoceras* are post-Canadian. The range alone suggests, though it does not prove, that they belong to the family Endoceratidae. It still remains to be determined whether they represent a natural stock, or whether perhaps we have grouped under this generic name species in the family which have achieved annuli in several different stocks.

From the genotype and *C. clarki* the following diagnosis of the genus is developed: Shells large, straight, surface with annuli varying from low and closely spaced to well elevated and relatively distant. Cross section of shell slightly depressed. Sutures straight and transverse. Siphuncle large, close to the venter, the siphuncle wall holochoanitic and typical of the Endoceratidae. Endocones are subcircular, faintly compressed in section, terminating in a central endosiphotube. The latest endocones, observed only in *C. clarki*, are de-

pressed elliptical, subangular laterally, and are deposited on earlier cones with a marked unconformity. Endosiphoblades have not yet been observed in the genus, nor has the apex of the shell or siphuncle.

Because of the annuli of the surface, *Cyclendoceras* has been recognized from small fragments of shells. Many such specimens are not adequate for close comparison of the species. Further, it is quite possible that among them there are some representing more than one stock in which annuli developed within the Endoceratidae. On the basis of surface features alone, it is possible to trace gradations from smooth shelled Endoceratidae, through species with rugose surfaces, those with the rugosity developed into low closely spaced annular markings, to those with well elevated distant annuli. Gradation into members of the Endoceratidae with smother surfaces is indicated. However, *Cyclendoceras* appears to be differentiated by Lowville time, and, curiously, the apparent gradation on the basis of external shell features has been observed only in species which are materially younger. It is therefore possible (1) that such younger species may represent development of annuli in an independent stock within the Endoceratidae, or (2) that they may represent a species group of *Cyclendoceras* returning to an externally simpler shell. While some confusion surrounds the proper limit of the genus *Endoceras*, it is evident that in typical material the siphuncle has endocones of depressed elliptical section. In most such material the cones terminate in a tube which is located in the ventral half of the siphuncle. If some annulated shells of the middle Trenton stem from such species of *Endoceras*, it should eventually be possible to determine this matter, for similar endosiphuncles would be expected. However, up to the present, no such annulated shells have been found retaining any part of the endosiphuncle.

A review of the species of *Cyclendoceras*, or rather of the aspect of *Cyclendoceras*, suggests most strongly that in the main the genus is a natural and a valid one, essentially confined to boreal Ordovician associations, ranging from Black River through Red River and into Richmond beds. At the same time, there remains a group of eastern species, mainly found in the Trenton, which can conceivably be homeomorphs more closely related to *Endoceras*, sensu stricto.

The oldest form known to the writer is a specimen which he collected from the Lowville limestone near Watertown, New York. Annuli are moderately low, fairly closely spaced, but well rounded and distant enough that there can be no confusion with the group of doubtful Trenton species noted above. The siphuncle has endocones of circular section, terminating in a central endosiphotube. The Chaumont limestone of the same region has yielded a portion of a living chamber of a *Cyclendoceras* with rather narrow well elevated annuli. Nothing is known of its internal structure, and the Chaumont has not as yet yielded any endosiphuncles recognizable as typical of *Cyclendoceras*. The equivalent "Leray" limestone of Ottawa has yielded a shell attaining a width of three inches. Externally the annuli are low, rounded, and only faintly elevated. The siphuncle shows cones terminating in a centrally located tube. A flattened fragment of a shell represents the genus in the Chaumont or Rockland equivalent of La Cloche Island. The genotype, *C. annulatum*, is from the Trenton, presumably the Rockland equivalent, near Watertown, New York. Its annuli are low, grading into concave interspaces, but are broad and rather widely spaced. The endocones clearly terminate in a central tube, but nothing is known of their cross section.

The Hull beds in Quebec, notably in the beds of the Jacques Cartier river south of Pont Rouge, and near the powerhouse, and the Riverier Ste. Anne south of St. Casimir, Quebec, have yielded endoceroids in numbers, all apparently a *Cyclendoceras* with extremely low annuli. One living chamber, from near St. Casimir, shows a portion of a living chamber increasing in shell height from 80 to 100 mm., in a length of 260 mm. Annuli are faintly oblique, low, well rounded in the basal part and separated by rather wide flat interspaces. At the base the crests of the annuli are 10 mm. apart; in the middle they are slightly closer, six annuli occurring in a length of 50 mm., while in the adoral fifth of the specimen annuli become faint, closely spaced, rugose, indistinct.

Probably this feature is close to the aperture of the fully grown shell. No siphuncles have been found attached to shells showing surfaces at this locality, but those obtained separately show circular endocones terminating in a central tube. One specimen also shows an apical end of a siphuncle. It is rather poorly preserved, but appears to be of the *Nanno* type. Abundant isolated siphuncles of the Jacques Cartier River have circular cones terminating centrally, and consistent with what is known of *Cyclendoceras*.

The typical Sherman Fall of New York has yielded a few rather large flattened endoceroids with very low indistinct closely spaced annuli. They are very large shells, and are believed to be a modification of the group of *Endoceras proteiforme* rather than true *Cyclendoceras*. No endosiphuncles typical of *Cyclendoceras* have been obtained from these beds. A fragment very similar in external markings was found in the middle Trenton of the Montmorenci River, Quebec.

Typical upper Trenton limestones of New York, Ontario and Quebec have yielded no shells identificable even tentatively as *Cyclendoceras*. The Ordovician shales of Gaspé have yielded *Cyclendoceras clarki*. This is the only representative of the genus in northeastern North America in any beds younger than the Hull.

The real metropolis of the genus is found in the Red River faunas, which the writer (Flower, 1956*a*) regards as equivalent to the Cobourg and Eden. No species have been recorded from the Cape Calhoun beds of northern Greenland. Teichert (1937) identified *C. popoagiense* and *C.* sp. from Melville Peninsula, and *C.* sp. from Cockburn Island. Foerste (1928) figured and described *C. boreale* from erratics at Port Burwell, Labrador, and *C.* sp. from beds at Mt. Beaufort, which are certainly Ordovician rather than Silurian. The Nelson limestone of Hudson Bay (Foerste & Savage, 1927) yielded *C. kindlei*. *C. whiteavesi* is reported from all three members of the Red River series of southern Manitoba (Foerste, 1929). There is here certainly more than this one species, some specimens showing large distant annuli, while others, essentially commensurate with them, have low closely spaced annuli. *Cyclendoceras* is the dominant endoceroid of the Dog Head member, is extremely rare in the Cat Head member, and is far less common than smooth shelled "*Endoceras*" in the Selkirk member.

A number of species have been described from the Bighorn group, all of them from the Lander sandstone member, in an association of Red River aspect. They are *C. abundum*, *C. costelliferum*, *C. cylindricum*, *C. depressum*, *C. expansum*, *C. longum* and *C. popoagiense* (Miller, 1932; Foerste, 1935).

The Fremont limestone of Colorado gives us our next glimpse of a Red River association. Sweet (1955) has recognized *Cyclendoceras* here, but did not attempt specific determination. The Montoya group of southern New Mexico and western Texas contains a Red River fauna in its lower part. From this association the writer has collected several fragments of *Cyclendoceras*. A fragment of the genus has been collected by the writer from the Burnam limestone of the Llano uplift.

The eastern Maysville and its equivalents have yielded no recognizable *Cyclendoceras* in eastern North America, nor have Richmond beds in Anticosti, Quebec, Ontario, New York or the Cincinnati arch. Foerste (1936) described a number of species from the Maquoketa shale of Iowa. They all have rather low closely spaced annuli. *C. atkinsonense* is extreme in this respect, *C. clermontense* is little better, but *C. thomasi* is more typical of the genus in wider spacing of the annuli. Beneath the Maquoketa the Dubuque beds have yielded endoceroids (Miller & Furnish, 1944), one of which, though assigned to *Endoceras*, has annuli quite like those of *Cyclendoceras* in proportion. This is *Endoceras clarkei* Miller & Kummel (1944). Such annuli are shown on the holotype, which represents a relatively early portion of a phragmocone, but are not apparent on other specimens of larger diameter which represent appreciably later portions of the shells.

There are no definite records of *Cyclendoceras* from Richmond beds overlying beds of Red River age, as in the upper part of the Montoya of New Mexico, the Fremont of Colorado or the Bighorn group of Wyoming, where Red River and succeeding Richmond deposits have not been fully differentiated, or in the Stony Mountain

formation of southern Manitoba or the Shamattawa limestone of Hudson Bay.

So few species of *Cyclendoceras* are known from more than gross features of surface markings, cross section, position and size of siphuncle, and spacing of septa, that the unity of the genus cannot be confirmed from the morphological evidence now available. However, the fact that *Cyclendoceras* shows a distribution pattern similar to that of many other cephalopod genera developed in boreal Ordovician faunas, suggests that the stock is probably largely, if not completely monophyletic. It is perhaps significant that the few dubious and exceptional species noted above occur in faunas the boreal affinities of which are not readily apparent.

Only one species of *Cyclendoceras* has been reported outside of North America. This is *Cyclendoceras orientale* Kobayashi (1934). It is a large straight annulated endoceroid, the siphuncle unusually large in proportion to the diameter of the shell, and atypical in that the termination of the endocone is extremely close to the ventral margin of the siphuncle.

CYCLENDOCERAS CLARKI Flower, n. sp.
Pl. 62, figs. 1–4

The species is based upon a single specimen, 290 mm. long, consisting of a siphuncle with part of the ventral wall of the shell retained in the anterior portion. There the shell shows close low rounded annular markings, four in a length of 15 mm., where the length of the camera is 12 mm. There is not enough of the shell to show its original proportions, but the venter is quite strongly rounded in cross section, less flattened than in many Endoceratidae, the shell width is estimated at 70 and its height at 60 mm. here.

The siphuncle increases gradually from a diameter of 11 mm. at the apical end to 30 mm. in 250 mm., and in the anterior 40 mm. shows slight crushing, but was apparently uniformly expanded originally. The siphuncle is subcircular in cross section, tending to be faintly compressed, the height about 2 mm. greater than the width. Septal markings indicate four camerae in a length of 25 mm. near the base of the specimen, and two in an equal length near the anterior end. A longitudinal section shows holocoanitic septal necks, and there is indication of the usual connecting rings lying within them. The siphuncle is largely filled with endocones, the endosiphocone occupying the anterior 100 mm., and adorally where it thins, there is slight crushing of the siphuncle. Sections near the base of the specimen show the endocone material too recrystallized to show more than the central position of the endosiphotube. Farther forward, cross sections show the endocones to form a simple pattern, departing from the cross section of the siphuncle only in being slightly compressed. This is shown clearly in pl. 62, fig. 4, where the siphuncle measures 25 mm. in width, 23 mm. in height, being very slightly distorted by crushing here. A second section, 60 mm. farther forward, shows a circular siphuncle 30 mm. across. The outer endocones are subcircular, very faintly compressed in cross section. However midway toward the center of the endocone material there is an abrupt change, the later cones being depressed and elliptical in cross section, subangular laterally, and presenting a sharp contrast with the earlier ones (pl. 62, fig. 2). A longitudinal section taken of the region between these two sections, shows the disconformable nature of the early and late endocones. In the section, the endosiphocone widens from a tiny central tube to a width of 16 and a height of 9 mm. in the length of 60 mm.

Discussion.—This species is a significant one as it supplies definite information on the nature of the siphuncle wall and the pattern of the endocones in *Cyclendoceras* for the first time. The species is a relatively small one, distinctive in the low and very closely spaced annulations, a feature in which it differs strongly from *Cyclendoceras annulatum* (Hall).

Holotype.—McGill University, Redpath Museum.

Occurrence.—From "black shale, 2300' east of Anse Pleureuse Cove, north shore of the Gaspé Peninsula, Quebec." The shales are probably of late Trenton age.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 459–476, PLS. 63–68, 2 TEXT-FIGS., MAY 1958

SOME MISSISSIPPIAN CONODONTS FROM THE HIGH RESISTIVITY SHALE OF THE NANCY WATSON NO. 1 WELL IN NORTHEASTERN MISSISSIPPI

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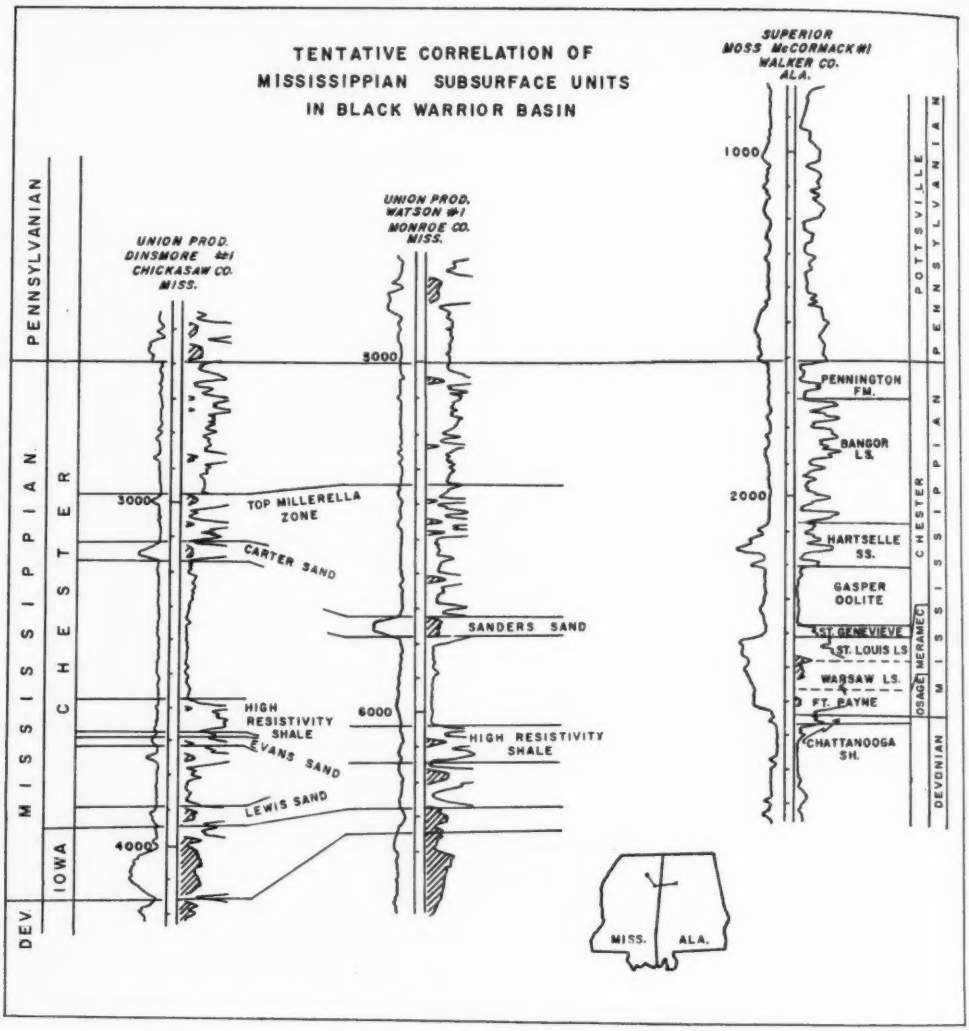
ABSTRACT—A conodont fauna consisting of twenty-three species, six of which are thought to be new, is described from the upper Mississippian High Resistivity black shale of the Union Producing Company's Nancy Watson No. 1 well in Monroe County, northeastern Mississippi. The species are placed in the conventional form-species requiring reassignment of two species that were originally designated as members of assemblage-species. The six new species are *Hindeodella pachymandıla*, *Hindeodella redunca*, *Lonchodina epilonca*, *Neoprioniodus alytus*, *Ozarkodina deflecta*, and *Ozarkodina pachyamba*. The conodont fauna of the High Resistivity shale is compared with described upper Mississippian species from the Union Producing Company's Dinsmore No. 1 well, thirty miles to the northwest, in Chickasaw County, Mississippi, and with the lower Heath formation in Montana. Several species of conodonts known to occur in the upper Mississippian black shale of the Dinsmore well, and several other species of conodonts known to occur in the Heath formation, are found in the High Resistivity shale. Inasmuch as there are no conodont species that are known to occur in both the upper Mississippian black shale of the Dinsmore well and the lower Heath formation, it is suggested that the High Resistivity shale from the Nancy Watson well falls stratigraphically between these formations.

INTRODUCTION

THE Black Warrior Sedimentary Basin, which was named after the Black Warrior River that flows through western Alabama, is a triangular-shaped area that includes approximately 35,000 square miles located in northeastern Mississippi and northwestern Alabama. The boundaries of this basin are said, by Mellen, 1947, to be the southwesterly plunging Appalachian folds which border it on the east and the plunging Ouachita Mountain system which borders it on the west. The high Ordovician areas of central and western Tennessee form the northern boundary.

Discovery of gas and some oil in the Mississippian Chester sands of the central portion of the Black Warrior Basin has given the region added interest to the petroleum industry. Correlation within the basin, however, has presented major problems. The larger divisions of the Mississippian system, namely the Iowa and Chester, can be recognized within the basin. Smaller units, on the other hand, have presented much difficulty in interpretation, mainly because there is a rapid change in facies in less than eighty miles from predominantly carbonates in northern Alabama to predominantly clastics in northeastern Mississippi. To add to the problem, the individual sands of the Chester in the area are not continuous as blanket sands, but are absent or poorly developed in many wells (text-fig. 1). The Mississippian Geological Society has named the sands by using names of the farms in which the sands were first productive or well developed rather than tying them in with the surface names of the Alabama area (text-fig. 1). Fossil evidence like-wise has been scanty, thereby hindering correlation with the Alabama section.

In March of 1952, the Union Producing Company provided information helpful to correlation by coring a good portion of its Nancy Watson No. 1 well located at 1026 feet south and 1023 feet west of the northeast corner of Section 31, Township 15 south, Range 7 east in Monroe County, Mississippi. The company started diamond coring in the Pennsylvanian at 2801 feet and continued until the Devonian was reached at 6732 feet. This series of cores as well as those of the Neal No. 1 well in Monroe County and the Dinsmore No. 1 well in Chickasaw County, which were also cored by the Union Producing Company, have provided some of the best sections of the



TEXT-FIG. *1*

Mississippian available in Mississippi. Unfortunately, the cores were not preserved and, except for the few samples collected by the oil companies, the remainder has lain at the mercy of the weather and livestock. The Neal cores were so badly trampled by cattle that they were worthless by 1954 and the other two are probably in a similar condition, at this writing.

SCOPE OF PRESENT PAPER

When the cores were first made available, macrofossils were collected both by the oil companies and the United States Geological Survey. The present study represents a further attempt to make information available about the fossils of the cores, and is concerned with conodont faunas found in the High Resistivity shale of the Union Producing Nancy Watson No. 1 well between depths 6040 feet and 6140 feet. The shale can best be described as sooty, blocky shale that is intercalated with thin silty layers. Linguloid brachiopods and sponge spicules

are rare to common in the upper part of this shale, whereas in the lower part the above fossils tend to be rare or absent. Fish teeth are found in the lowermost zones, but were not observed in the upper ones.

An attempt is made to establish a conodont zonation of the High Resistivity shale and to suggest tentative correlations with other areas.

ACKNOWLEDGMENTS

The author is indebted to E. H. Rainwater of Jackson, Mississippi, who first suggested this problem as a thesis topic, and to Dr. Frank M. Swartz, without whose many helpful suggestions, criticisms, and encouragements this paper would not have been possible.

Special thanks are also due F. R. Schroeder of the Union Producing Company for permission to use a portion of Messrs. Stuart J. Pike and W. E. Taylor's core description of the Nancy Watson No. 1 well.

STRATIGRAPHY OF THE CONODONT OCCURRENCES IN THE NANCY WATSON NO. 1 WELL

When the Mississippian part of the Nancy Watson core was sampled, a lithologic description of the High Resistivity shale was not made because a detailed faunal study of this shale was not anticipated. Consequently, in order to present a complete picture of the section, the Union Producing Company's description of the core from 6016 feet to 6164 feet is here included.

6016–6068 52′ SHALE, dark gray, slightly silty, slightly micaceous, thin bedded, occasional mudstone in bottom 20′.

6068–6118 50′ SHALE, dark gray, slightly silty, very slightly micaceous.

6118–6146 13′ SHALE, dark gray, to black, slightly silty, very slightly micaceous, occasional thin streaks of sand.

1½′ LIMESTONE, black, dense, concoidal fracture, fractures lined with secondary calcite. (This limestone was not present when the samples were collected.)

7½′ SHALE, dark gray, to black, slightly silty, very slightly micaceous, occasional thin streaks of sand.

2′ SANDSTONE, dark gray, fine to medium granined, very shaley, slightly calcareous.

4′ SHALE, dark gray, to black, slightly silty, very slightly micaceous, occasional thin streaks of sand.

6146–6164 15′ SHALE, dark gray, to black, with occasional thin streaks of light gray mudstone.

Since the core had weathered about two years before samples were collected, certain lithologic units were more noticeable than they presumably had been when the core was first described. During sampling, it was noticed that there is a marked lithologic change in the core at about 6040 feet from highly weathered gray shale to a more resistant, blocky, sooty, black shale. As observed in the field, this black shale continued to 6140 feet where there is again a marked lithologic change from the resistant black shale to highly weathered gray shale. The boundaries of the black shale as seen in the field agree very closely with those picked on the electric log of the well.

Samples were taken within the black shale at the five following depths: 6040 feet, 6060 feet, 6100 feet, 6125 feet, and 6140 feet. Conodonts occur in all of the samples collected from these horizons in rare to moderate numbers. The gray shales found immediately above and below the black shale were sampled at 5999 feet, 6016 feet, 6150 feet, and 6164 feet. A detailed examination was made of samples from these gray shales and no conodonts were found.

Of the conodonts found between 6040 feet and 6140 feet, 25 species have been recognized (see Table 1 and text-fig. 2). The following species are thought to be new:

Hindeodella pachymandala Stanley, n. sp.
Hindeodella redunca Stanley, n. sp.
Neoprioniodus alytus Stanley, n. sp.
Lonchodina epilonca Stanley, n. sp.
Ozarkodina deflecta Stanley, n. sp.
Ozarkodina pachyamba Stanley, n. sp.

The distribution of the observed conodont species is shown in text-fig. 2. Some of the species, such as *Hindeodella montanaensis* and *Hindeodella redunca*, are found in all the samples collected. *Hindeodella* sp. B should probably be included in this group inasmuch as it occurs in all samples except those from 6100 feet and 6125 feet. Other species appear to be confined, in the present collection, to certain depths. A tentative zonation is attempted based on the present

TABLE 1—CONODONTS FOUND IN THE HIGH RESISTIVITY SHALE OF THE NANCY WATSON WELL AND IN THE BLACK SHALE OF THE DINSMORE WELL

Species	Watson Well	Dinsmore Well
Cavusgnathus sp.		×
Geniculatus claviger (Roundy)		×
Gnathodus bilineatus (Roundy)	×	×
Gnathodus inornatus Hass	×	×
Hindeodella ensis Hass		×
Hindeodella montanaensis (Scott)	×	
Hindeodella pachymandala Stanley, n. sp.	×	
Hindeodella redunca Stanley, n. sp.	×	
Hindeodella undata Branson & Mehl		×
Hindeodella sp. A	×	
Hindeodella sp. B	×	
Ligonodina roundyi Hass	×	
Lonchodina epilonca Stanley, n. sp.	×	
Lonchodina paraclarki Hass	×	
Lonchodina sp. A	×	
Lonchodus sp. A	×	
Lonchodus sp. B	×	
Lonchodus sp. C	×	
Metalonchodina sp. A		×
Neoprioniodus alytus Stanley, n. sp.	×	
Neoprioniodus inclinatus (Hass)		×
Neoprioniodus sp. cf. *N. ligo* (Hass)		×
Neoprioniodus sp. cf. *N. roundyi* (Hass)		×
Neoprioniodus singularis (Hass)	×	×
Neoprioniodus sp. A	×	
Ozarkodina deflecta Stanley, n. sp.	×	
Ozarkodina pachyamba Stanley, n. sp.	×	
Prioniodina montanaensis (Scott)	×	
Prioniodina sp. A	×	
Prioniodina sp. B	×	
Prioniodina sp. C	×	

collection and realizing that these zones may be extended vertically when more information is available.

The oldest subzone in the Nancy Watson well is based on samples taken at 6140 feet in the well and contains the following species: *Gnathodus bilineatus*, *Ligonodina roundyi*, *Lonchodus* sp. A, and *Lonchodus* sp. C.

The central subzone of the Nancy Watson well extends from 6100 feet to 6125 feet and is based on samples taken from these two depths, The fauna is distinguished by *Gnathodus inornatus*, *Hindeodella pachymandala*, *Prioniodina* sp. A, *Neoprioniodus alytus*, and *Neoprioniodus* sp. A.

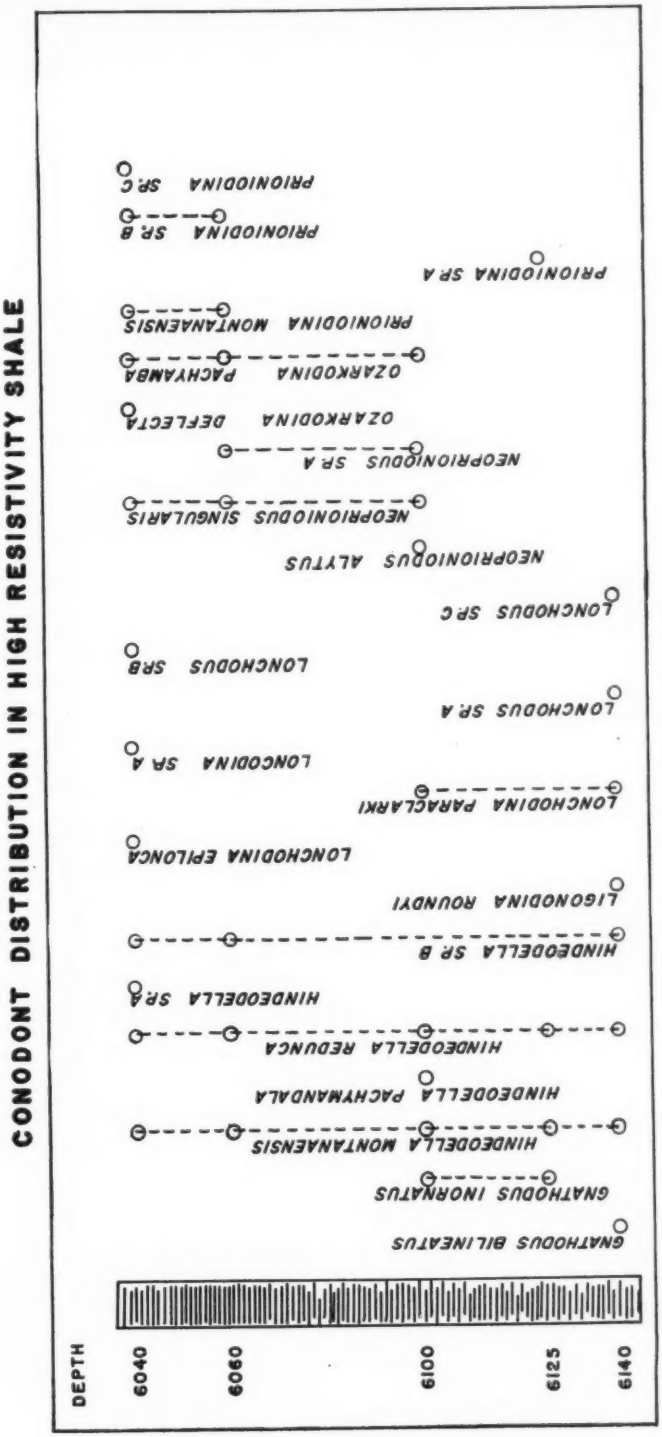
The uppermost subzone of the Nancy Watson well is based on samples taken from 6040 feet and 6060 feet and is characterized by the following species: *Hindeodella* sp. A, *Lonchodina epilonca*, *Lonchodina* sp. A, *Lonchodus* sp. B, *Ozarkodina deflecta*, *Prioniodina montanaensis*, *Prioniodina* sp. B, and *Prioniodina* sp. C.

Neoprioniodus singularis, *Ozarkodina pachyamba*, and *Lonchodina paraclarki* do not fit into any of the tentatively advanced zones, but in general *Neoprioniodus singularis* and *Ozarkodina pachyamba* appear to be confined in the present collection to the upper part of the High Resistivity shale and *Lonchodina paraclarki* to the lower part.

COMPARISON OF THE CONODONT FAUNA OF THE HIGH RESISTIVITY SHALE OF THE NANCY WATSON WELL WITH SOME OTHER CONODONT FAUNAS OF SIMILAR AGE

The conodont fauna of the black shale between depths 3576 feet and 3682 feet of the Union Producing Company's Dinsmore well in Chickasaw County, Mississippi, thirty miles northwest of the Nancy Watson well, has been described by Hass (1953). On the bases of eleven significant conodont species, he concluded that this shale was Late Mississippian, Early Chester in age. The species found in this black shale, as well as those occurring in the High Resistivity shale of the Watson well, are compared in Table 1 and text-figure 2. It should be noted that only three of the eleven species of the black shale of the Dinsmore well described by Hass have been found among the twenty-three species of the High Resistivity shale of the Nancy Watson well as described in this paper.

Scott (1942) described conodont assemblages from the lower part of the Heath formation of Montana, which is said to be Middle to Late Chester in age. Of the twenty-three species from the High Resistivity shale of the Nancy Watson well described in this paper, only two species appear to be represented among the many specimens illustrated by Scott from the lower


CONODONT DISTRIBUTION IN HIGH RESISTIVITY SHALE
GNATHODUS BILINEATUS
GNATHODUS INORNATUS
HINDEODELLA MONTANAENSIS
HINDEODELLA PACHYMANDALA
HINDEODELLA REDUNCA
HINDEODELLA SP A
HINDEODELLA SP B
LIGONODINA ROUNDYI
LONCHODINA EPILONCA
LONCHODINA PARACLARKI
LONCODINA SP A
LONCHODUS SP A
LONCHODUS SP B
LONCHODUS SP C
NEOPRIONIODUS ALTUS
NEOPRIONIODUS SINGULARIS
NEOPRIONIODUS SP A
OZARKODINA DEFLECTA
OZARKODINA PACHYAMBA
PRIONIODINA MONTANAENSIS
PRIONIODINA SP A
PRIONIODINA SP B
PRIONIODINA SP C
DEPTH
6040
6060
6100
6125
6140

TEXT-FIG. 2

part of the Heath formation. These two forms, which were included within assemblage-species by Scott, are placed in conventional form-species in the present paper for the purpose of comparison. The two species that are common to both wells are:

Hindeodella montanaensis (Scott)
Prioniodina montanaensis (Scott)

CONCLUSIONS

Relations of the known conodont fauna of the High Resistivity shale of the Watson well to conodonts of the black shale of the Dinsmore well and to conodonts of the lower part of the Heath formation are summarized in Table 2. It should be noted here that the latter formations, which are believed to be of Early Chester and Middle to Late Chester ages respectively, have no conodont species in common.

TABLE 2—COMPARISON OF NUMBER OF CONODONT SPECIES IN HIGH RESISTIVITY SHALE WITH OTHER AREAS

Conodont species found in the High Resistivity shale of the Nancy Watson well	23
Conodont species found in the black shale of the Dinsmore well	11
Conodont species found in the lower part of Heath formation (there was no attempt made, at this time, to reassign all of Scott's assemblage-species to form species)	?
Conodont species common to the High Resistivity shale of the Watson well and the black shale of the Dinsmore well	3
Conodont species common to the High Resistivity shale of the Watson well and the lower part of the Heath formation	2
Conodont species common to the black shale of the Dinsmore well and the lower part of the Heath formation	0

The data summarized in Table 2 tend to lead to the following conclusions:

1. Although several conodont species of the High Resistivity shale of the Nancy Watson well also occur in the black shale of the Dinsmore well, and although several other conodont species of the High Resistivity shale of the Nancy Watson well occur in the lower part of the Heath formation, the respective faunas in general differ so that it appears likely that the High Resistivity shale of the Nancy Watson well is not closely equivalent to either of the other two horizons.
2. No conodont species are known to be common to the black shale of Early Chester age of the Dinsmore well and the beds of Middle to late Chester age of the lower part of the Heath formation. On the other hand, several conodont species of the High Resistivity shale of the Nancy Watson well are known in the black shale of the Dinsmore well and several other conodont species are known in the lower part of the Heath formation. Therefore, it appears that the conodont fauna of the High Resistivity shale of the Nancy Watson well is more closely related to the conodont faunas of the other two horizons than the conodont faunas of those two horizons are related to each other. It accordingly is suggested that the High Resistivity shale of the Nancy Watson well is intermediate in age and stratigraphically falls between the black shale of Early Chester age of the Dinsmore well and the beds of Middle to Late Chester age of the lower part of the Heath formation.

To aid further consideration of the conclusions tentatively advanced in the above paragraphs, much more work needs to be done on the Chester conodonts. One possibility would be to discover conodont zones in the Chester limestones associated with the black shales in sub-surface sections in Mississippi, or in surface sections farther northeast in Mississippi, Alabama, and Tennessee. More detailed studies of the conodonts of the black shales of the Nancy Watson and Dinsmore wells might also clear up many of the present problems.

SYSTEMATIC DESCRIPTIONS

Genus GNATHODUS Pander, 1856

GNATHODUS BILINEATUS (Roundy)

Pl. 68, fig. 7

Polygnathus bilineata Roundy, 1926, U. S. Geol. Survey Prof. Paper 146, p. 13, pl. 3, figs. 10a-c.
Polygnathus texana Roundy, 1926, U. S. Geol. Survey Prof. Paper 146, p. 14, pl. 3, figs. 13a,b.
Gnathodus bilineatus (Roundy), Hass, 1953, U. S. Geol. Survey Prof. Paper 243-F, p. 78, pl. 14, fig. 25–29.

Oral view.—Axis of single specimen curved inward approximately 15 degrees with most of flexure located at junction of blade and carina.

Cup asymmetrical; outer side expanded so width approximately equals length; anterior edge is straight, approximately at right angles to axis of specimen and is widest portion of cup; cup ornamented with five rows of concentric nodes that approximately parallel the outer and posterior edge of cup and terminate on anterior edge.

Inner side of cup somewhat higher, especially at the anterior end and is ornamented by ridges that have their axis at right angles to axis of specimen.

Blade in oral view is a little narrower than carina and thins anteriorly.

Lateral view.—Carina highest at anterior end, contains seven denticles that are fused and have their steepest edge anterior.

The length of the single specimen is 1.7 mm.

Relationships.—This specimen very closely resembles those illustrated by Hass (1953) from the upper Barnett formation. A minor variation in comparing the specimens is that the degree of flexure of the blade with the carina is approximately five degrees greater in the single observed specimen from the High Resistivity shale than those from the upper Barnett formation. However, it is felt at this time that this is well within the variation of the species.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi, depth 6140 feet.

GNATHODUS INORNATUS Hass
Pl. 68, figs. 5,6

Spathognathodus commutatus Branson & Mehl, 1941, Denison Univ., Sci. Lab., v. 35, p. 172, pl. 5, figs. 19–22.

Gnathodus inornatus Hass, 1953, U. S. Geol. Survey Prof. Paper 243-F, p. 80, pl. 14, figs. 9–11.

Blade wide; lateral ridge present, crest located one-third distance from oral edge.

Denticles near anterior end of blade tend to be discrete, pointed, curved posteriorly; approaching posterior end, denticles tend to become fused, blunt; posterior end of carina deflected slightly downward. Denticles of carina and blade combined average fifteen in number.

Average length of three specimens is 0.75 mm.

Relationships.—The rectangular outline of this specimen in lateral view and, so far as could be determined, the lack of ornamentation of the cup indicate close relationship to *G. inornatus* Hass.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet to 6125 feet.

Genus HINDEODELLA Bassler, 1925
HINDEODELLA MONTANAENSIS (Scott)
Pl. 64, figs. 1–4,5 (in part)

Lochriea montanaensis, Scott, 1942, Jour. Paleontology, v. 16, no. 3, pl. 39, fig. 7, not figs. 1,4, and 9; pl. 40, fig. 18, not figs. 2,9,10,12,13,15, and 19.

Posterior bar long, straight, tapering at distal end to a point that is deflected orally; bar slightly biconvex to flat sided at anterior end becoming more convex posteriorly. Oral edge of bar rounded, aboral edge grooved.

Posterior denticles pointed, sharp edged, biconvex in section, deflected posteriorly making an angle of approximately 63 degrees with bar at anterior end. Denticles are of two main sizes; longer ones approximately twice length of shorter ones and usually separated by two to four shorter ones; thirteen to twenty large denticles present. Denticles on anterior end of bar are straight, but toward posterior end become increasingly curved with concave side anterior.

Cusp slightly curved posteriorly, biconvex, double edged, and long; length being greater than twice length of longer teeth on posterior bar.

Anterior bar expanded and sharply deflected inward; contains approximately five denticles that are about the same length as longer denticles on posterior bar.

A large specimen is about 2.8 mm. in length.

Lectotype.—Scott's illustrated specimen (1942, pl. 40, fig. 18) is chosen as the lectotype.

Relationships.—Scott's assemblage species are separated in this paper and placed in the more conventional form-species for the purposes of comparison.

The posterior portion of *Hindeodella montanaensis* (Scott) is very similar to that

of *Hindeodella redunca* Stanley, and in many cases one may not be able to differentiate between the two species if the anterior portion is not present. However, the posterior bar of *H. montanaensis* generally tends to be straight while that of *H. redunca* tends to be slightly arched.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet to 6140 feet.

HINDEODELLA PACHYMANDALA
Stanley, n. sp.
Pl. 63, fig. 5

Posterior bar long, slightly arcuate, biconvex in section becoming compressed at distal extremity.

Posterior denticles discrete, long, straight, acutely pointed, biconvex, and inclined posteriorly approximately 40 degrees from the vertical; two distinct sizes of denticles present, usually alternating with one or two shorter denticles between longer ones. However, in some cases two long denticles are found adjacent to one another without the shorter denticle between.

Cusp long, pointed, curved posteriorly, compressed at base and becoming biconvex toward tip.

Anterior bar short, compressed, wide, oral edge round, aboral edge sharp, anterior end flexed inward; denticles on anterior bar discrete, near cusp generally tend to be sharp edged while those at distal end tend to be circular in section.

Escutcheon small and located directly beneath cusp.

The length of the single specimen is 2.9 mm.

Holotype.—The specimen illustrated on pl. 63, fig. 5 is designated as the holotype, U.S.N.M. 133385.

Relationships.—This species is differentiated from *Hindeodella ensis* Hass by a narrower, more convex posterior bar; a rounded, rather than beveled, aboral edge; and discrete, rather than needle-like, almost fused, smaller sized denticles.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet.

HINDEODELLA REDUNCA Stanley, n. sp.
Pl. 63, figs. 1–4

Posterior bar long, straight to slightly arched, biconvex in section, aboral edge grooved, oral edge rounded. Denticles biconvex, closely set and of two major sizes that alternate with two to six short thin denticles between longer heavy ones. Both sizes of denticles are inclined posteriorly, becoming more inclined and concave toward

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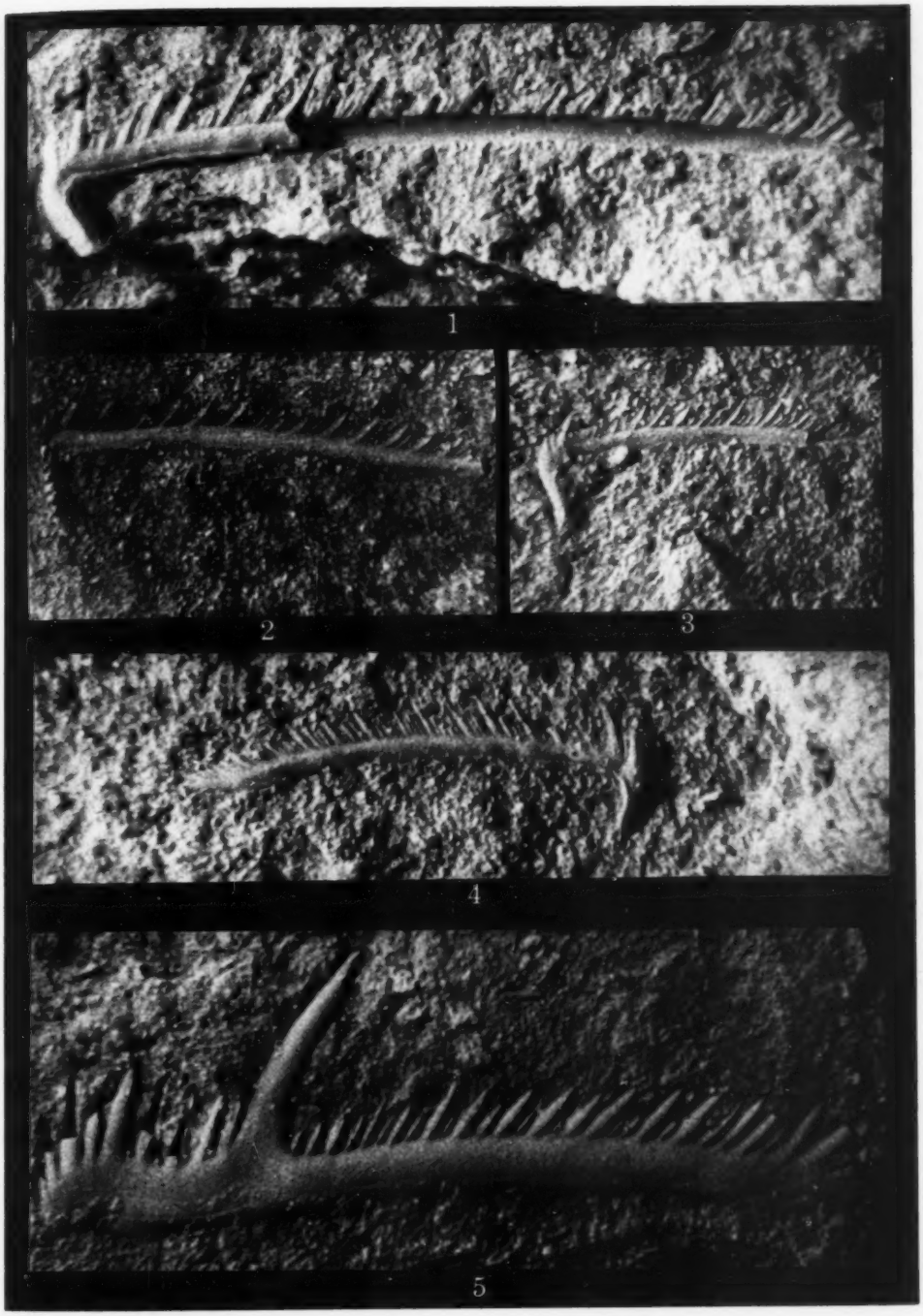
EXPLANATION OF PLATE 63

All figures unretouched photographs, ×40

FIGS. *1–4*—*Hindeodella redunca* Stanley, n. sp. *1*, an outer, lateral view of a large incomplete specimen that has a complete mold of the missing portion of the posterior bar. The illustration shows the gentle arching of the denticulated posterior bar and the sharp downward and inward deflection of the anterior bar, which are characteristic of this species. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet; paratype, U.S.N.M. 133382. *2*, an inner, lateral view of an almost complete specimen illustrating the denticles along the entire length of the inner side of the anterior bar. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet; holotype, U.S.N.M. 133381. *3*, an outer, lateral view of a small specimen that has an incomplete posterior bar. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet; paratype, U.S.N.M. 133383. *4*, an outer, lateral view of a complete specimen illustrating the arched posterior bar that is common to many specimens of this species. In addition, the cusp is complete in this specimen. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet; paratype, U.S.N.M. 133384.

5—*Hindeodella pachyamba* Stanley, n. sp. A lateral view of a nearly perfect specimen. The illustration shows the slightly compressed anterior bar; the posterior bar is gently convex throughout its entire length, but becomes compressed at the distal end. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet; holotype, U.S.N.M. 133385.


1
2
3
4
5

1
2
3
4
5

cusp as they approach distal end of bar.

Cusp is longer than any of denticles; straight to slightly curved and directed posteriorly.

Anterior bar is compressed and deflected about 100 degrees to 115 degrees downward and inward just anterior to cusp and is denticulated on the oral edge throughout its entire length.

The length of a large specimen is 3.0 mm.

Holotype.—The specimen chosen as the holotype is the one illustrated on pl. 63, fig. 2, U.S.N.M. 133381; paratypes, U.S.N.M. 133382, 133383, 133384.

Relationships.—This species is quite common throughout the entire black shale section of the Watson well. The posterior bar, as seen in the fragment specimens of this species, resembles that of *Hindeodella montanaensis* (Scott), especially if a straight rather than an arched bar is found. The main differentiating characteristic is the anterior bar in *H. redunca*. It is curved inward, downward, and backward instead of just inward, as in *H. montanaensis*.

This species is not put in the genus *Hamulosodina* Cooper because it has denticles throughout the entire length of the anticusp rather than "only near the cusp," as defined by Cooper (1931). Furthermore, the author is inclined to agree with Ellison (1946) in that *Hamulosodina* is a junior synonym of *Hindeodella*.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet to 6140 feet.

HINDEODELLA sp. A
Pl. 66, fig. 8

Bar heavy, straight, long, with apical lip; aboral edge flat, oral edge rounded.

Denticles of two distinct sizes; longer ones pointed, inclined approximately 10 degrees from the vertical, separated by one to four shorter denticles that are one-third to one-half the length of longer ones. Both sizes of denticles are biconvex and decrease in length posteriorly.

The length of the single incomplete specimen is 3.3 mm.

Relationships.—This description is based on a single fragment. The specimen differs from *Hindeodella* sp. B in that the bar is more massive in appearance, contains a smaller number of discrete denticles between the longer ones and the denticles are posteriorly inclined at a greater angle.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

HINDEODELLA sp. B
Pl. 66, figs. 6,7

Bar long, thin, compressed; oral edge

EXPLANATION OF PLATE 64

All figures are unretouched photographs, ×40

FIGS. *1–4*—*Hindeodella montanaensis* (Scott). *1*, an outer, lateral view of a specimen that has the distal portion of the posterior bar missing. The illustration shows the short, inwardly deflected, posterior bar and the long, pointed, posteriorly directed cusp. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet. *2*, an outer, lateral view of a complete specimen that has the anterior portion of the posterior bar broken and slightly off-set. The illustration shows a complete, long, straight, denticulated posterior bar, the slightly inclined, gently curved cusp, and the denticulated anterior bar. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6060 feet. 3, an outer, lateral view of a specimen that has an incomplete distal portion of the posterior bar; the anterior bar is somewhat more expanded than is usually common to this species. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6060 feet. *4*, an outer, lateral view of a small specimen that has the major portion of the posterior bar missing. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet.

5—*Hindeodella montanaensis* (Scott) and *Prioniodina montanaensis* (Scott). A mold of *H. montanaensis* in contact with a complete specimen of *P. montanaensis*. Both of these species occur in Scott's assemblage-species *Lochriea montanaensis* from the lower part of the Heath formation. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6060 feet.

rounded, aboral edge flat and flanged to form an apical lip.

Denticles of two distinct sizes, with three to eight shorter denticles separating longer ones. Shorter denticles approximately one-fourth to one-third length of longer ones. Both sizes of denticles straight, biconvex, and inclined approximately five degrees from the vertical.

The length of a large incomplete specimen is 3.3 mm.

Relationships.—The above description is based on the two illustrated fragmental specimens. This species differs from *Hindeodella* sp. A in that the bar is not as massive, has a greater number of discrete denticles separating the longer ones and the denticles are more gently inclined.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depths 6040 feet, 6060 feet, and 6140 feet.

Genus LIGONODINA Bassler, 1925
LIGONODINA ROUNDYI Hass
Pl. 68, figs. 3,4

Prionidus sp. A., Roundy, 1926, U. S. Geol. Survey Prof. Paper 146, p. 11, pl. 4, fig. 9.
Prioniodus sp. C., Roundy, 1926, U. S. Geol. Survey Prof. Paper 146, p. 11, pl. 4, fig. 11.
Ligonodina roundyi, Hass, 1953, U. S. Geol. Survey Prof. Paper 243-F, p. 82, pl. 15, figs. 5–9.

Cusp long, pointed, round in horizontal section; deflected posteriorly with most of curvature taking place near base.

Anticusp directed slightly anteriorly, length in lateral view one-third that of cusp; inner side of anticusp supports approximately four denticles that have their axis at right angles to that of bar and anticusp.

Posterior bar short, massive; oral edge rounded, aboral edge flat. Bar is believed to be complete and supports two blunt, straight, apparently complete denticles.

The average length of the two observed specimens is 0.45 mm.

Relationships.—These specimens agree closely with those illustrated by Hass, 1953, from the upper Barnett formation.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

Genus LONCHODINA Bassler, 1925
LONCHODINA PARACLARKI Hass
Pl. 67, fig. 1

Lonchodina paraclarki, Hass, 1953, U. S. Geol. Survey Prof. Paper 243-F, p. 83, pl. 16, figs. 15,16.

Cusp long, heavy, curved, with most of curvature taking place in lower portion leaving remainder of cusp relatively straight. Cusp divided into two parts by sharp edges forming a highly convex outer side and a somewhat flatter, smaller, inner side. A large escutcheon occupies the entire area under cusp.

Anterior bar straight, deflected downward; in transverse section compressed, height and width less than posterior bar, oral edge rounded and aboral edge flat and flanged. Denticles of anterior bar discrete, oval in section, and gently curved toward cusp; anterior bar of single specimen supports seven denticles.

Posterior bar straight, the smaller angle with anterior bar is approximately 95 degrees; in transverse section height greater than width, oral edge rounded, aboral edge flat and expanded to form apical lips. Denticles on posterior bar discrete, long, pointed, curved toward cusp; in section denticles oval with narrower edge posterior; bar of single specimen supports five denticles.

Tooth in general is bowed inward.

The length of the single figured specimen is 1.2 mm.

Relationships.—This specimen differs from Hass's type specimens by its moderately, rather than closely spaced denticles, its longer anterior bar, and the posterior bar which is approximately equal in length to that of the cusp. However, it should be noted that both bars of Hass's specimen and the specimen illustrated in this paper are terminally incomplete and their true length may be even greater than illustrated. The curvature of the cusp is somewhat more gentle in the specimen illustrated in this paper than the specimens figured by Hass, but in other respects is similar with two sharp edges dividing the cusp into a smaller inner side and a larger outer one.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

LONCHODINA EPILONCA Stanley, n. sp.
Pl. 67, fig. 2

Cusp long, stright, pointed, round in horizontal section and directed anteriorly.

Anterior bar straight in lateral view; slightly bowed inward in oral view; oral edge rounded, aboral edge flat and flanged to form apical lips; in transverse section height greater than width. Anterior denticles on single specimen four in number, inclined anteriorly, curved with concave side toward cusp.

Posterior bar bowed inward, in transverse section has greater height than width; oral edge rounded, aboral edge thin, flat, and expanded to form apical lips. Denticles on single specimen nine in number, inclined anteriorly, curved with the concave side toward cusp.

Smaller angle between anterior and posterior bars in lateral view is approximately 100 degrees.

The length of the single figured specimen is 1.0 mm.

Holotype.—The specimen illustrated on pl. 67, fig. 2 is chosen as the holotype, U.S.N.M. 133389.

Relationships.—*Lonchodina epilonca* is differentiated from *Lonchodina distans* Huddle by its flat, flanged, rather than rounded aboral edge. In addition, *Lonchodina epilonca* differs by having a straight cusp and posterior denticles that are slightly concave toward the cusp.

Lonchodina epilonca differs from *Lonchodina prava* Huddle by having a straight cusp throughout rather than one that is strongly bent at the base.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

LONCHODINA sp. A
Pl. 67, fig. 3

Cusp long, straight, and directed anteriorly; in horizontal section cusp circular.

Anterior bar incomplete; in transverse section height greater than width; supports one straight, peg-like denticle that is approximately three-fourths length of cusp.

Posterior bar long, strongly arched, and compressed; denticles discrete, round in horizontal section; straight in lateral view proximal to cusp, becoming concave toward cusp near distal end; eleven denticles present on single specimen.

The length of the single specimen is 1.6 mm.

Relationships.—*Lonchodina* sp. A differs from *Lonchodina epilonca* by its strongly arched posterior bar and by the absence of the apical lips on the anterior and posterior bars.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

Genus LONCHODUS Pander 1856
LONCHODUS sp. A
Pl. 65, fig. 8

Bar long, straight, flat sided; in transverse section height is greater than width; oral edge rounded; aboral edge flat and flanged with flange very pronounced at one end of bar, thinning, and almost disappearing at the opposite end. Each end of bar in single observed specimen appears to be incomplete.

Denticles long, straight, pointed, heavy and of two distinct sizes, longer ones being approximately twice length of shorter ones. Denticles of both sizes approximately normal to bar. Single observed specimen supports nine denticles.

The length of the single specimen is 1.0 mm.

Relationships.—*Lonchodus* sp. A is differentiated from *Lonchodus* sp. B by the two distinct lengths of denticles that have approximately the same diameter.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

LONCHODUS sp. B
Pl. 65, fig. 9

Bar long, straight, flat sided; in transverse section height greater than width; oral edge rounded, aboral edge flat and expanded to form apical lips. Each end of bar in single observed specimen appears to be incomplete.

Denticles subequal, discrete, oval in section, approximately verticle to bar; den-

ticles of two distinct types, a heavy denticle that alternates with a thinner one that is usually shorter.

The length of the single specimen is 0.9 mm.

Relationships.—This species is differentiated from *Lonchodus* sp. A by the alternating heavy and thin, subequal denticles.

The shorter, stubbier denticles of the described specimen may be due to breaking and regeneration and in actuality, the denticles of a perfect specimen may be of approximately equal length.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

LONCHODUS sp. C
Pl. 65, fig. 6

Bar straight, long, width approximately equal to height; oral edge rounded, aboral edge flat and flanged to form apical lips.

Denticles discrete, pointed, sharp edged, straight; form an angle of approximately 78 degrees with bar. On single observed specimen, which has both ends of bar broken, seven denticles are present.

The length of the single specimen, including the mold, is 1.75 mm.

Relationships.—*Lonchodus* sp. C resembles very closely *Lonchodus simplex*, as illustrated by Hass (1953). It differs from his specimen in that the angle between the bar and denticles of *Lonchodus* sp. C is slightly larger.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

EXPLANATION OF PLATE 65

All figures are unretouched photographs, ×40

FIG. *1*—*Prioniodina montanaensis* (Scott). An illustration of the lateral view of an almost complete specimen showing the straight anterior bar, the gently curved posterior bar, and the slightly curved denticles that tend to be concave toward the cusp. The escutcheon is located beneath the cusp and is markedly expanded. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

2—*Prioniodina* sp. C. A lateral view of what is believed to be a complete specimen illustrating the straight anterior and posterior bars and the short, wide-based denticles. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

3—*Prioniodina* sp. A. A lateral view of a complete specimen showing the straight anterior bar and the arched, narrower posterior bar. A small escutcheon is located under the cusp. Denticles on both bars are straight, narrow, and peg-like. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6125 feet.

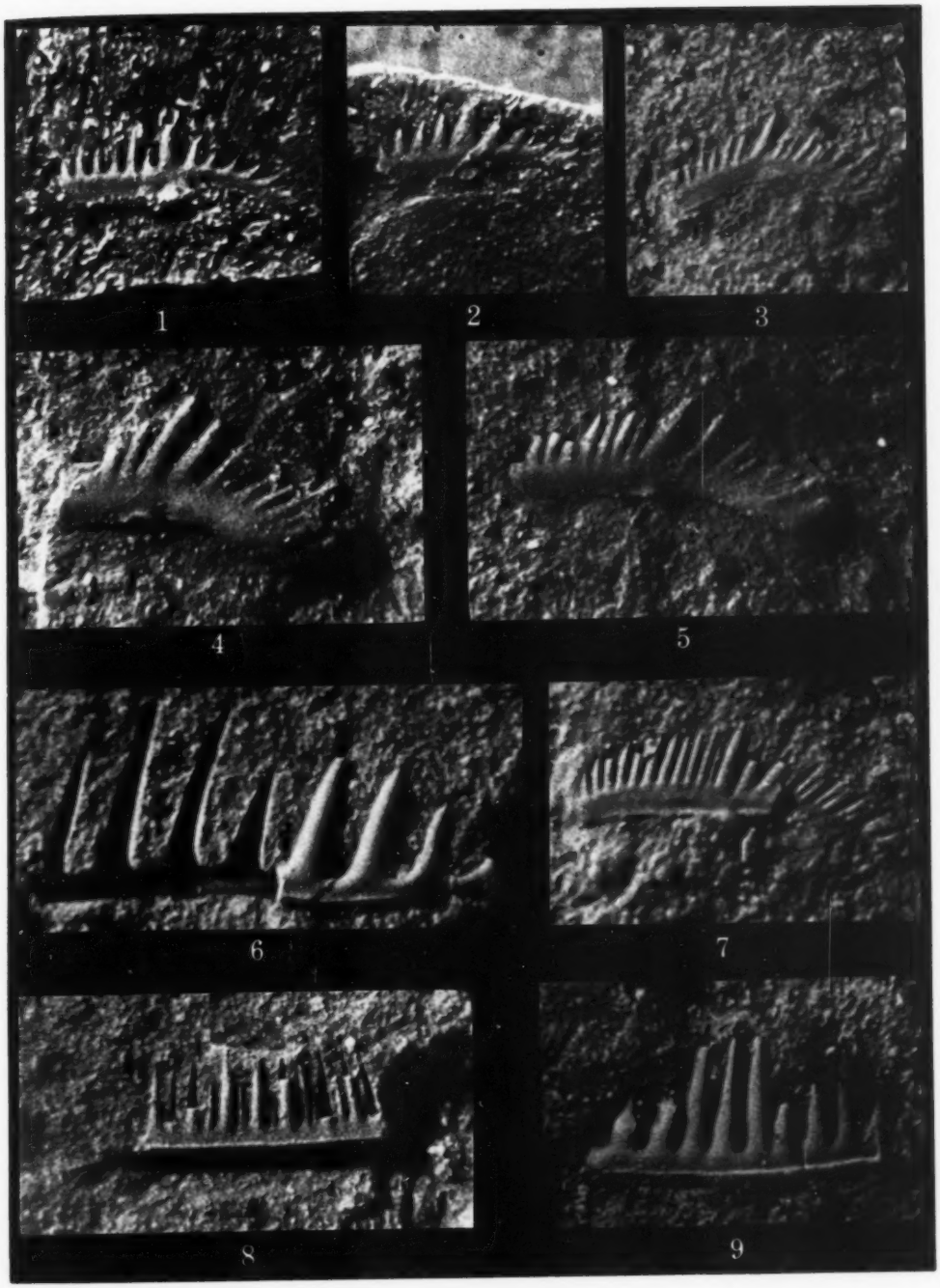
4,5—*Ozarkodina deflecta* Stanley, n. sp. *4*, a lateral view of an incomplete specimen showing a portion of the anterior bar, the cusp, and the complete posterior bar. This specimen is somewhat larger than the complete specimen illustrated in figure 5. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet; paratype, U.S.N.M. 133387. *5*, a lateral view of an almost complete specimen showing the large, approximately centrally located cusp; the straight bars join at an angle thereby deflecting one of the bars downward in relation to the other. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet; holotype, U.S.N.M. 133386.

6—*Lonchodus* sp. C. A lateral view of an incomplete specimen illustrating the straight bar with an apical lip. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

7—*Prioniodina* sp. B. A lateral view of an incomplete specimen that has the major portion of the posterior bar missing. The illustration shows the compressed anterior and posterior bars, the round peg-like denticles, and the apical lip which is pronounced in the central portion of the specimen and thins distally. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6060 feet.

8—*Lonchodus* sp. A. A lateral view of a fragmentary specimen; illustration shows two distinct types of denticles on the bar, a long, heavy denticle alternating with a more slender, generally shorter denticle. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

9—*Lonchodus* sp. B. A lateral view of a fragmentary specimen; illustration shows complete denticles of varying lengths on a straight bar. Some of the shorter, stubbier denticles may be the result of breaking and regeneration. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.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NEOPRIONIODUS Rhodes & Müller, 1956

NEOPRIONIODUS ALYTUS

Stanley, n. sp.

Pl. 66, fig. 1

Cusp heavy, long, straight, pointed; inclined slightly forward forming an angle of approximately 95 degrees with bar; anterior edge sharp, posterior edge rounded.

Anticusp triangular in lateral view; anterior edge sharp and continuous with anterior edge of cusp; posterior edge thick, flat, and expanded to form flange that continues onto aboral edge of bar where it terminates at about two-thirds length of bar.

Denticles straight, pointed, sharp edged, biconvex, closely set, but discrete; denticles at anterior end of bar approximately vertical, but become increasingly inclined and shorter in length posteriorly.

The length of the single observed specimen is 0.63 mm.

Holotype.—The specimen illustrated on pl. 66, fig. 1 is chosen as the holotype. U.S.N.M. 133388.

Relationships.—This species differs from *N. roundyi* in that the cusp is shorter in length, with the anterior edge sharp and the posterior edge rounded. The posterior edge of the anticusp flares out and gracefully joins the bar, which is short and supports discrete denticles. The angle between the bar and cusp is approximately 95 degrees as contrasted to approximately 115 degrees for the same angle in *N. roundyi.*

This species differs from *Neoprioniodus scitulus* (Branson & Mehl) in that the posterior edge of the cusp is rounded and not sharp. *N. scitulus* also lacks the flared apron joining the anticusp and bar.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet.

NEOPRIONIODUS SINGULARIS (Hass)

Pl. 66, figs. 2,3

Prioniodus singularis Hass, 1953, U. S. Geol. Survey Prof. Paper 243-F, p. 88, fig. 4, pl. 16.

Cusp long, pointed, sharp edged, biconvex; curved inward with all of curvature taking place in basal part leaving upper portion of cusp relatively straight. Cusp markedly inclined anteriorly forming an obtuse angle with bar of approximately 150 degrees.

EXPLANATION OF PLATE 66

All figures are unretouched photographs, ×40

FIG. *1*—*Neoprioniodus alytus* Stanley, n. sp. A lateral view of a specimen that has the upper half of the cusp missing. The length of the posterior bar is believed to be complete. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet; holotype, U.S.N.M. 133388.

2,3—*Neoprioniodus singularis* (Hass). *2*, the lateral view of the outer side; the lower portion of the cusp, the complete anticusp, and the bar are missing and only appear as a mold. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet. 3, a lateral view of the inner side; the upper portion of cusp and distal end of bar are missing from this specimen. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

4,5—*Neoprioniodus* sp. A. *4*, the lateral view of the outer side of an almost complete specimen showing the anteriorly inclined cusp and a short posterior bar. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet. *5*, the lateral view of inner side of an incomplete specimen. The tips of both the cusp and anticusp are missing from this specimen. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet.

6,7—*Hindeodella* sp. B. *6*, a lateral view of a fragmentary specimen showing the long, heavy denticles alternating with shorter, more slender denticles. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6060 feet. *7*, a lateral view of an incomplete specimen illustrating the decrease in length posteriorly of the longer, heavier denticles. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

8—*Hindeodella* sp. A. A lateral view of an incomplete specimen illustrating the long, heavy, lipped-bar with two distinct sizes of denticles that decrease in length posteriorly. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

Anticusp inclined posteriorly; anterior edge thin, straight to slightly curved, continuous with anterior edge of cusp; posterior edge thick and flat with edge beveled.

Bar short, straight; oral edge rounded, aboral edge flat; in transverse section bar biconvex and about twice as high as wide.

Denticles straight, sharp edged, biconvex, and bent inward; inward curvature is in basal portion leaving remainder of denticle straight; denticles tend to decrease in size posteriorly; denticle proximal to cusp is, in part, fused with cusp.

The average length of two specimens is 0.38 mm.

Relationships.—The distal portions of both of the illustrated specimens are incomplete. This species somewhat resembles *N. ligo* (Hass), but is differentiated from it by having an angle between the bar and cusp of approximately 150 degrees.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet to 6100 feet.

NEOPRIONIODUS sp. A
Pl. 66, figs. 4,5

Cusp long, slender, compressed, with sharp anterior and posterior edge; directed forward forming an obtuse angle of approximately 110 degrees with posterior bar; cusp bowed inward with curvature being evenly distributed over entire area of cusp.

Anticusp about one-fifth length of cusp; compressed, triangular in lateral view; directed forward with anterior edge forming an angle of approximately 140 degrees with anterior edge of cusp.

Bar compressed, length about one-third that of cusp. Denticles long, straight, compressed, sharp-edged, and decreasing in length posteriorly.

The average length of two specimens is 0.25 mm.

Relationships.—*Neoprioniodus* sp. A. is differentiated from *Neoprioniodus singularis* in that it is more compressed, has an anteriorly directed anticusp and in lateral view has a smaller angle between the cusp and the bar. The cusp is gently bowed inward with the curvature evenly distributed throughout the entire cusp rather than being concentrated in the basal portion.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet.

Genus OZARKODINA Branson & Mehl, 1933
OZARKODINA DEFLECTA Stanley, n. sp.
Pl. 65, figs. 4,5

Anterior bar straight, blade-like, compressed with broadest portion in transverse view near oral edge; aboral edge sharp. Denticles approximately eight in number, straight, pointed, sharp edged, closely set, but discrete; tending to decrease in size toward distal end of bar.

Posterior bar straight, narrow in lateral view; in transverse view broader than anterior bar. Denticles nine to twelve in number; straight, pointed, sharp-edged, closely set, but discrete; denticles become more inclined and shorter in length toward posterior end of bar.

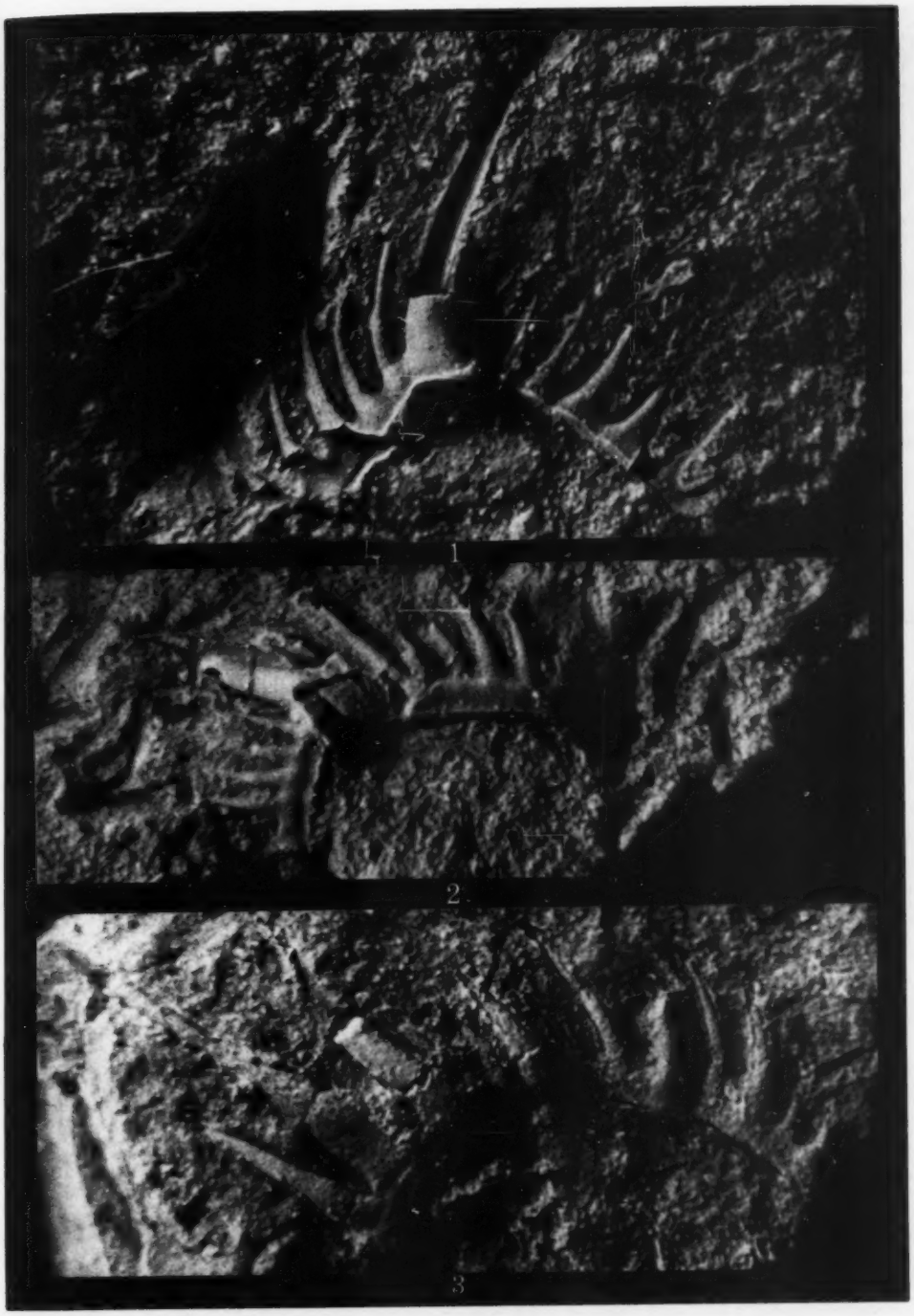
EXPLANATION OF PLATE 67

All figures are unretouched photographs, ×40

FIG. *1*—*Lonchodina paraclarki* Hass. A lateral view of the outer side of what is believed to be an almost complete specimen. The illustration shows a long, curved cusp with most of the curvature taking place near the base. Both bars are approximately equal in length and offset in relation to one another. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

2—*Lonchodina epilonca* Stanley, n. sp. A lateral view of a specimen that has the lower portion of the cusp and the adjacent portion of the anterior and posterior bars damaged. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet; holotype, U.S.N.M. 133389.

3—*Lonchodina* sp. A. A lateral view of a highly weathered or leached specimen. Anterior bar, which is probably incomplete, supports one straight, peg-like denticle, Posterior bar is arched and supports eleven denticles. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.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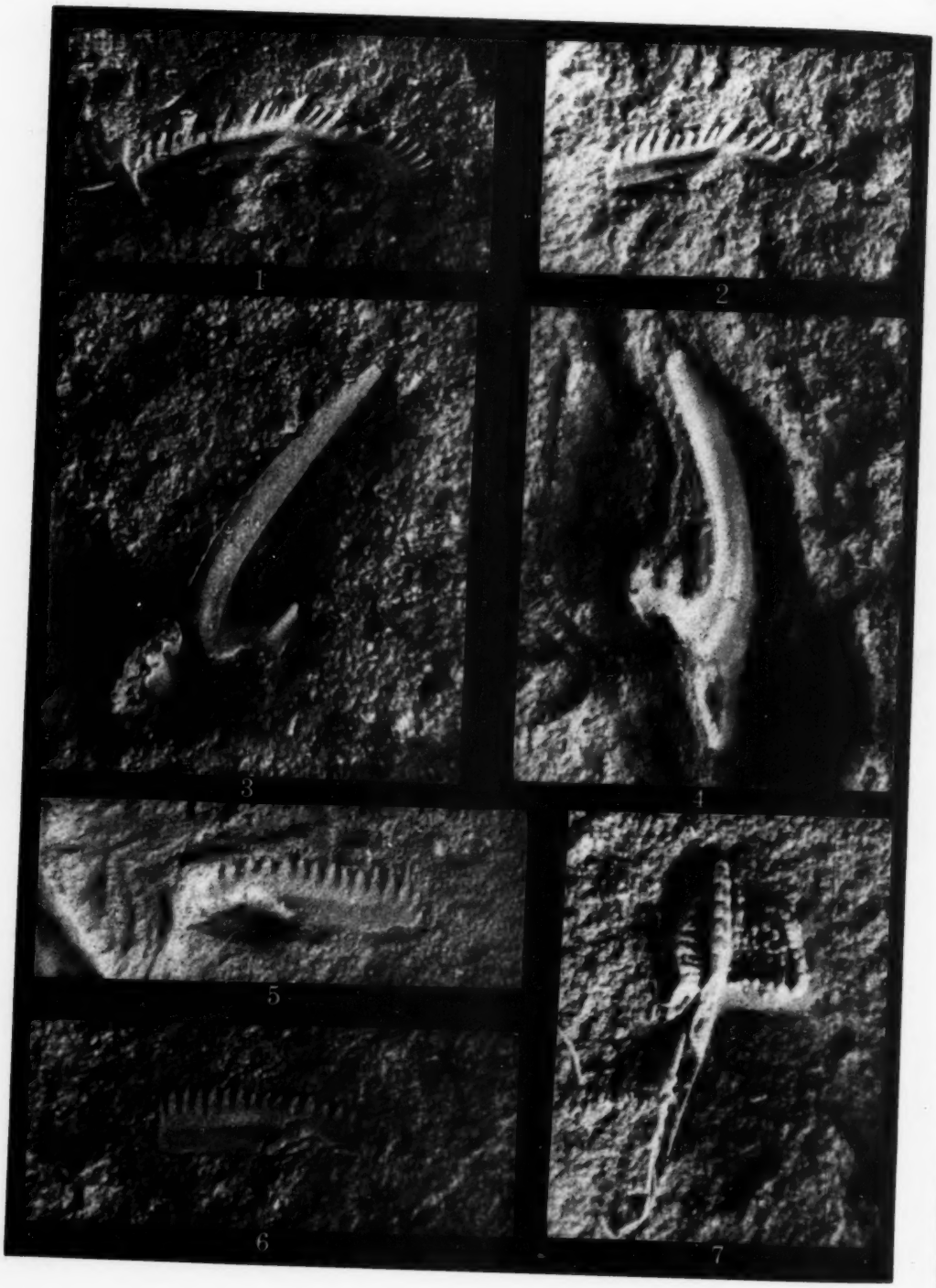
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Cusp straight, pointed, sharp-edged, approximately twice as wide and one-third to one-half longer than adjacent denticles.

Anterior bar bent downward approximately 25 degrees from plane of posterior bar. Escutcheon small and located under cusp.

The average length of two specimens is 1.1 mm.

Holotype.—The specimen illustrated on pl. 65, fig. 5, in this paper is chosen as the holotype, U.S.N.M. 133386; paratype, pl. 65, fig. 4, U.S.N.M. 133387.

Relationships.—*Ozarkodina deflecta* Stanley appears to resemble Cooper & Sloss's figure (1943, pl. 29, fig. 12) of *Ozarkodina regularis* Branson & Mehl. However, upon examing Branson & Mehl's original description and illustrations, *O. deflecta* is definitely not *O. regularis* Branson & Mehl. *Ozarkodina deflecta* is differentiated from *O. regularis* by its much narrower anterior and posterior bars that are straight rather than arched and by the denticles that are discrete rather than fused.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

OZARKODINA PACHYAMBA Stanley, n. sp.
Pl. 68, figs. 1,2

Tooth consisting of approximately equal anterior and posterior bars that in lateral view form a continuous arch. Oral edge of both bars expanded; aboral edge markedly thinned and grooved as observed in aboral view.

Cusp sharp edged, pointed, directed posteriorly, thicker than largest denticle; laterally confluent with, and approximately one-third longer than, adjacent denticles.

Denticles sharp edged, pointed, laterally confluent; inclined posteriorly, and in general tending to become shorter and concave toward the cusp at the distal ends of both bars. On observed specimens, anterior bar contains eight to twelve denticles; posterior bar contains ten to fifteen denticles; on both bars, more slender denticles are interspaced irregularly with thicker denticles.

Escutcheon in lateral view triangular in shape and located under cusp.

The average length of two observed specimens is 1.2 mm.

Holotype.—The specimen illustrated on pl. 68, fig. 1 is chosen as the holotype.

EXPLANATION OF PLATE 68

All figures are unretouched photographs, ×40

FIGS. *1,2*—*Ozarkodina pachyamba* Stanley, n. sp. *1*, a lateral view of an almost complete specimen illustrating the expanded oral edge and the markedly thinned aboral edge that is characteristic of this species. The triangular shaped escutcheon is also well shown in this illustration. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet; holotype, U.S.N.M. 133390. *2*, a lateral view of a slightly smaller specimen that has the distal portion of the posterior bar missing. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet; paratype, U.S.N.M. 133391.

3,4—*Ligonodina roundyi* Hass. *3*, a lateral view of the inner side showing the denticulated anticusp. The short bar supports two denticles. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet. *4*, a lateral view of the outer side showing the anticusp, the short denticulated bar, and the long, gently curved cusp. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

5,6—*Gnathodus inornatus* Hass. *5*, a lateral view illustrating the rectangular shape of the specimen, the stub-like denticles of the carina, and the somewhat longer denticles of the blade. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6100 feet. *6*, a lateral view illustrating the lateral ridge present on the blade portion of the specimen. The cup of this specimen is incomplete. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6125 feet.

7—*Gnathodus bilineatus* (Roundy).—An oral view of a specimen illustrating the ornamentation of the cup. The blade portion of this specimen is incomplete. The main light in this photograph is from the lower right, in order to bring out the ornamentation on the inner cup. Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6140 feet.

U.S.N.M. 133390; paratype, pl. 68, fig. 2, U.S.N.M. 133391.

Relationships.—This species somewhat resembles *Subbryantodus roundyi* Hass. However, the expanded lateral ridge along the oral edge and the triangular shape of the escutcheon in lateral view are the differentiating features.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

Genus PRIONIODINA Ulrich & Bassler, 1926

PRIONIODINA MONTANAENSIS (Scott)

Pl. 65, fig. 1

Lochriea montanaensis, Scott, 1942, Jour. Paleontology, v. 16, no. 3, pl. 40, figs. 9,10; not figs. 2,12,13,15,18,19.

Anterior bar short, straight, slightly biconvex; posterior bar gently arched, slightly biconvex; longer and narrower than anterior bar.

Anterior denticles five to six in number, subequal in length, discrete, pointed; round in horizontal section; approximately normal to bar and slightly concave toward cusp.

Posterior denticles subequal in length, discrete, round in horizontal section, shorter in length than anterior denticles; straight to slightly curved toward cusp; inclined posteriorly with angle between denticle and bar decreasing distally.

Cusp slightly heavier and longer than denticles, round in horizontal section and slightly curved posteriorly in lateral view.

Escutcheon markedly expanded in lateral view.

The average length of two specimens is 0.7 mm.

Lectotype.—Scott's illustrated specimen (1942, pl. 40, fig. 9) is chosen as the lectotype.

Relationships.—As far as can presently be determined, this specimen very closely resembles the specimen illustrated by Scott (1942) in pl. 40, figs. 9 and 10, of his assemblage-species *Lochriea montanaensis*. It differs slightly from these specimens, however, by having gently curved, rather than straight, posterior denticles. *Prioniodina montanaensis* also resembles the specimen of *Prioniodina* sp. C illustrated in pl. 65, fig. 2, of this paper but differs from it in that the denticles are more slender, especially at the base, the posterior bar is curved downward a little more, and the escutcheon is larger.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

PRIONIODINA sp. A

Pl. 65, fig. 3

Anterior bar straight, compressed; aboral edge rounded, aboral edge slightly expanded to form apical lip. Posterior bar slightly biconvex and moderately arched downward.

Anterior denticles on single specimen six in number; pointed, round in horizontal section, and gently curved toward cusp.

Posterior denticles on single specimen eight in number, subequal in length, pointed, round in horizontal section and gently curved toward cusp.

Cusp straight, pointed, round in horizontal section and approximately twice length of adjacent denticles.

Escutcheon very small and located under cusp.

The length of a single specimen is 0.75 mm.

Relationships.—This specimen somewhat resembles *Prioniodina montanaensis* but differs from that species in that the anterior bar is markely compressed, the posterior bar is more strongly arched, and the escutcheon is very small rather than expanded.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6125 feet.

PRIONIODINA sp. B

Pl. 65, fig. 7

Anterior bar compressed; in transverse section bar about twice as high as wide, oral edge rounded, aboral edge flat and expanded to form apical lip on exposed side that is pronounced at central portion of specimen under cusp and thins distally.

Posterior bar compressed near anterior end, becoming slightly biconvex and thinner distally; in transverse section near cusp bar about twice as high as wide; oral edge rounded, aboral edge flat and expanded to form apical lip, which terminates approximately mid-length of posterior bar.

Anterior denticles slightly inclined posteriorly with reference to oral edge of bar

and in general appear to decrease in length distally; eleven denticles present on single specimen found.

Posterior denticles fourteen on single specimen; long, straight, peg-like; tend to alternate with a shorter more slender denticle; inclined and decreasing in length posteriorly.

Cusp straight, longer and heavier than denticles on either anterior or posterior bars. Escutcheon small, very slightly expanded and located under cusp.

The length of the single specimen is 1.1 mm.

Relationships.—This specimen differs from *Prioniodina montanaensis* because of its longer, straighter denticles, and its very small escutcheon.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6060 feet.

PRIONIODINA sp. C
Pl. 65, fig. 2

Anterior bar short, straight, oral edge expanded, aboral edge compressed. Posterior bar slightly longer than anterior bar; biconvex near oral edge, becoming sharp at aboral edge; in lateral view approximately straight, becoming narrower distally.

Anterior denticles on single specimen four in number, straight, discrete, elliptical in section, wide at base, becoming acutely pointed at tip.

Posterior denticles on single specimen five in number, straight, pointed, elliptical in section, tend to be shorter than anterior denticles and become steeply inclined toward distal end of bar.

Cusp straight, pointed, elliptical in section, twice as wide at base and about one-fourth longer than adjacent denticles.

Escutcheon located under cusp.

The length of a single specimen is 0.65 mm.

Relationships.—*Prioniodina* sp. C resembles *Prioniodina montanaensis* but differs from it by having straight denticles that are very wide at their base; a moderate, rather than a large escutcheon, and an essentially straight rather than an arched posterior bar.

This specimen also resembles *Prioniodella galea* Elias illustrated by Elias (1956, pl. 2, fig. 54). However, the presence of the cusp definitely puts the specimen illustrated in this paper in the genus *Prioniodina*. This specimen also differs from Elias's illustration by having broader based anterior and posterior denticles, and a shorter, broader cusp.

Occurrence.—Union Producing Company's Nancy Watson No. 1 well, Monroe County, Mississippi; depth 6040 feet.

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THE BRAINCASE OF *CAMARASAURUS LENTUS* (MARSH)

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ABSTRACT.—The taxonomy of the genus *Camarasaurus* is discussed. On the basis of the material examined only two species (*supremus* Cope and *lentus* Marsh) are considered valid. An additional braincase of the problematical *Camarasaurus agilis* (Marsh) is briefly described. The braincase of *Apatosaurus ajax* Marsh is briefly described from the type specimen and a specimen in the American Museum of Natural History. The braincase and the internal aspects of several skull bones of *C. lentus* (Marsh) are described in detail and figured. The mode of articulation of the lower jaw with the quadrate and the type of wear of the teeth suggest that this herbivorous dinosaur chewed its food in the manner of the herbivorous mammals. The order of tooth replacement in herbivorous dinosaurs is discussed.

THE preparation of an "in place" exhibit of dinosaur remains at the quarry in Dinosaur National Monument has been under consideration by the National Park Service for at least three decades. The dip of the beds (67%) at the quarry, situated as it is on the south flank of the Split Mountain anticline near the east end of the Uinta Mountains, is ideal for this type of exhibit. Also the location of the quarry, on a hilltop nearly 400 feet above the Green River, provides an excellent view of the surrounding country.

At this late date it is impossible to determine who merits the credit for the idea of an "in place" exhibit. At least a dozen people have claimed the distinction of having been the first to make the suggestion to the late Mr. Earl Douglass while working the quarry for the Carnegie Museum. When and by whom the idea was conveyed to the National Park Service is also a mystery.

When work by the Carnegie Museum was terminated December 31, 1922, it was evident that it would be necessary to remove a large portion of the hill in order to prepare any sort of an "in place" exhibit. Funds for this work were made available during the 1930's and a cut was made through the hill along the strike of the beds. The depth of this cut will permit an exhibit nearly forty feet high. A length of one hundred and eighty feet for the exhibit has been arbitrarily decided upon.

Work on the exhibit was temporarily suspended in the fall of 1938 due largely to conditions of world unrest. At this time nearly twelve feet of bentonitic clay remained stratigraphically above the silicified sandstone which carries the principal concentration of dinosaur remains. The work of removing this portion of the overburden was resumed in September 1953. In the summer of 1955, during the course of this work, a connected series of vertebrae of an herbivorous dinosaur were encountered in the bentonitic clay near the west end of the exhibit area. When fully exposed the specimen was found to consist of a number of skull elements, a complete cervical series and six dorsal vertebrae with ribs.

Since the bentonitic clay in which the specimen was buried disintegrates with exposure to the air, the specimen was removed from the cliff for full preparation and preservation with plastics. The work in the laboratory revealed that the skull had macerated apart before burial. It was distributed along the cervical vertebrae and the elements were for the most part in an excellent state of preservation. Nearly all of the elements were recovered.

I wish to comment on the natural skill and dexterity exhibited by my two assistants, Floyd H. Wilkins and Frank N. McKnight, during the preparation of this specimen. Not only did they successfully preserve the thin laminae of the vertebral processes but also the paper thin edges of the skull elements. The results are all the more remarkable because it was their first attempt at laboratory preparation of vertebrate fossils.

I also wish to express my appreciation of the excellent illustrations drawn by Mr. Larry Isham, staff artist in the Department of Geology, United States National Museum, and Mr. Michael Insinna, staff artist in the Department of Geology and Paleon-

tology, American Museum of Natural History.

SYSTEMATICS

As the development of this specimen progressed it exhibited the very long cervical ribs characteristic of *Uintasaurus douglassi* Holland. Full preparation revealed that the two specimens were in complete agreement on the structure of the posterior cervical vertebrae as well as the length of the cervical ribs. The specimen of *Camarasaurus lentus* (Marsh) in the Carnegie Museum described by Gilmore in 1925 exhibits the same very long cervical ribs and the same details of the posterior cervical vertebrae. This is also true of the specimen of *Camarasaurus lentus* (Marsh) on exhibition in the United States National Museum from the Dinosaur National Monument. All of these specimens, including the type of *Uintasaurus douglassi* Holland, agree with the generic characters of *Camarasaurus* Cope as set forth by Osborn & Mook (1925, p. 376). Since the genus *Camarasaurus* was established by Cope in 1877 and the genus *Uintasaurus* was established by Holland in 1924 the latter must be relegated to the synonymy of the former.

Gilmore (1925, p. 352) recognized four species of *Camarasaurus—supremus* Cope, *grandis* Marsh, *robustus* Marsh, and *lentus* Marsh—but did not characterize them.

Through the courtesy of the United States National Museum, the Carnegie Museum, the Yale Peabody Museum and the American Museum of Natural History, it has recently been my privilege to examine the material in their care which pertained to this or closely related genera of sauropod dinosaurs. I shall include here such of my notes on the several specimens which appear to be pertinent to the subject.

Camarasaurus grandis (Marsh), 1877

Type description.—Apatosaurus grandis Marsh, O. C., Dec. 1877, Am. Jour. Sci., v. 14, p. 515.

Type material.—No. 1905, Y.P.M., occiput and frontal region, most of braincase, both quadrates and parts of both quadratojugals, most of both pterygoids, left maxilla with ascending process, most of both dentaries and surangulars, complete cervical series of vertebrae, most of the dorsals, anterior caudals, scapula and coracoid, and limb elements.

No. 1901, Y.P.M., numerous caudal vertebrae, both scapulae, humerus, radius, ulna, femur, tibia and fibula.

Locality.—Both specimens are from Como Bluff, Wyoming.

Remarks.—Specimen (no. 1905; Y.P.M.) is an immature individual and most of the sutures of the braincase can be determined. The occipital condyle is formed principally by the basioccipital. The exoccipitals rest on top of it and meet in the midline excluding the former from the foramen magnum. Anteriorly the basioccipital meets the basisphenoid in a nearly straight suture which passes across the anterior third of the tubera basioccipitalia. This suture passes upward on the side of the braincase but is lost in the area of the fenestra ovale. The foramen for the entrance of the internal carotid lies in this suture on the side of the braincase about 30 mm. above the lower extremity of the tubera.

The supraoccipital forms the superior border of the foramen magnum and the dorsal one fourth of the lateral borders. The suture between it and the exoccipital passes dorsolaterally so that the dorsal portion has a much broader extent than the ventral. The parietal contacts both the supraoccipital and the paroccipital process so that the supraoccipital is excluded from the border of the posttemporal fenestra which is an elongate narrow slit. The supratemporal fenestra is transversely elongate and rather narrow anteroposteriorly as in the skull under study. For the portion of the braincase preserved the cranial foramina agree in detail with those of *C. lentus* (Marsh).

In the portions of the skull preserved the sutures can be easily traced. On the vertebrae the sutures between the neural arch and the centrum are very evident. The surface of the vertebral centra and the elements of the limbs and girdles show the fibrous texture characteristic of young reptiles. In consideration of these facts, we are obliged to conclude that this specimen had not reached its full size. Judging by the growth conditions exhibited by the recent alligator and turtles and by the closed sutures in braincase under study and the type of

Apatosaurus ajax Marsh this specimen cannot have reached more than two thirds of its full size. Had this specimen lived long enough, it undoubtedly, would have grown to the size which Osborn and Mook (1921, p. 375), attribute to *Camarasaurus supremus* Cope. Consequently, this species must be considered a synonym of *C. supremus* Cope.

Measurements

Breadth across squamosals	281 mm.
Breadth across postorbitals	297 mm.
Height of quadrate	200 mm.

Camarasaurus robustus (Marsh), 1878

Type description.—*Morosaurus robustus* Marsh, O. C., Nov. 1878, Am. Jour. Sci., v. 16, p. 414.

Type material.—No. 1902, Y.P.M., left ilium.

Locality.—Como Bluff, Wyoming.

Remarks.—The surface of the bone shows the fibrous texture characteristic of young reptiles which have reached only about half their adult size. From the size of the specimen and massiveness of the bone it could easily be a very young specimen of *C. supremus* Cope and should be relegated to the snyonymy of that species.

Camarasaurus lentus (Marsh), 1889

Type description.—*Morosaurus lentus* Marsh, O. C., Apr. 1889, Am. Jour. Sci., v. 37, p. 333.

Type material.—No. 1910, Y.P.M., vertebral series from second cervical to eighth caudal, fourth cervical rib, left scapula, part of right coracoid, both humeri, left radius, both ilia, right pubis, left ischium, left femur, both tibia, and left hind foot.

Locality.—Como Bluff, Wyoming.

Referred material.—No. 11,338, Carnegie Museum, a nearly entire skeleton of a juvenile individual.

No. 13786 U.S.N.M., the skeleton of a fully mature individual which lacks the caudal vertebrae.

Present specimen. The skull, cervical vertebrae and six dorsals with ribs.

Remarks.—The type specimen has been mounted and placed on exhibition in the Yale Peabody Museum. That it is a juvenile specimen is shown by the uncoalesced sutures between the neural arches and the centra of the vertebrae. It is about the same size and same age stage as the specimen on exhibition in the Carnegie Museum.

In the specimen in the Carnegie Museum (C. M. 11,338) the supratemporal fenestrae are subcircular in outline but in the specimen on exhibition in the United States National Museum (No. 13786, U.S.N.M.) and the present specimen, both of which are fully mature, the fenestrae are elongate ellipses. This difference is, undoubtedly, an age character and the narrowing of the fenestra is accomplished by the upward growth of the occipital crest.

In the specimen in the Carnegie Museum the bifurcation of the neural spines of the cervical vertebrae begins with the seventh vertebra, with the fifth in No. 13786 U.S.N.M., and with the fourth in this specimen. This is, undoubtedly, an age character as the spines would be terminated in cartilage in the young individuals.

This species is considered valid.

Camarasaurus agilis (Marsh) 1889

Type description.—*Morosaurus agilis* Marsh, O. C., Apr. 1889, Am. Jour. Sci., v. 37, p. 334.

Type material.—No. 5384, U.S.N.M., occiput and frontal region, braincase, and cervical vertebrae 1 to 3.

Locality.—Canyon City, Colorado.

Referred material.—No. 545, A.M.N.H., occiput, frontal region and braincase from Bone Cabin Quarry, Wyoming. Collected by the Expedition of 1900.

Remarks.—The type specimen, an immature individual, was fully described and figured by Gilmore (1907) and I have nothing to add to his comments. However, the specimen in the American Museum of Natural History supplements the type in a number of details which will be included in this discussion.

An examination of the surface of the bone of the specimen in the American Museum does not reveal the fibrous texture characteristic of very young (half grown) reptiles. The suture between the basioccipital and the basisphenoid is completely obliterated. The alisphenoids are united along the midline for the entire distance between the olfactory and optic nerves. From all the criteria available on this specimen it is to

all intents and purposes a fully mature individual which has reached an age at which further growth will be negligible. These two specimens then represent the smallest true sauropod dinosaur yet known. Although an estimate of the body size based on the available material will be premature, it may be useful to give an opinion for whatever it may be worth. On the basis of the skull size and body size of the sauropods known from nearly entire skeletons this species would have a body size about equal to that of a 1600 pound horse. The length of neck and tail must await the discovery of a more nearly complete skeleton.

This species is obviously closely related to the relatively well known species of *Camarasaurus* and only those characters in which it differs will be mentioned. The alisphenoids are united along the midline for the entire distance between the optic and olfactory foramina. The exits for the optic nerve appear to be united across the midline into a single foramen. There is, however, in the foramen a broken scrap of bone which may or may not represent a broken septum. The ascending process of the alisphenoid abuts against the frontal along the anterior border of the supratemporal fenestra for about half of the width of the fenestra. This buttress is not continued down along the side of the braincase to form part of the crista antotica. The braincase is considerably damaged in this area but on the right side there is a low acute ridge along the anterior edge of the trigeminal foramen which represents an incipient crista antotica. There is considerable damage to the braincase in the area of the fifth and seventh nerves but the crista proötica appears to be a low acute ridge passing from the inferior edge of the paroccipital process ventrally to disappear on the side of the basipterygoid process of the basisphenoid.

The left tubera basioccipitalia and a part of the left basipterygoid process are present but considerably damaged. As near as they can be interpreted they resemble *Camarasaurus* in that the basisphenoid is produced below the basioccipital as a broad thick lamina of bone and the basipterygoid processes project ventrolaterally from it.

The occiput is fused into a solid sheet of bone and none of the stutures can be traced. The posttemporal fenestra is a oval opening about one and one half times as long as broad. The supraoccipital crest is a low but well defined ridge which extends from a short distance above the foramen magnum to the occipital crest.

The pineal foramen is rather large and roughly circular in outline. Its diameter is equal to half that of the foramen magnum.

The type of *Morosaurus agilis* Marsh has been fully described and figured by Gilmore (1907) and this specimen agrees with it in the several details in which they can be compared. On the basis of the third cervical vertebrae Gilmore (*ibid.*, p. 163) expressed the opinion that the species was valid but that it did not pertain to this genus. The characters presented by these two specimens show that the species is certainly a member of the family *Brachiosauridae*. Although this form is contemporary with *Camarasaurus* and *Apatosaurus* its braincase is a morphological type from which those of those two genera could easily be derived.

The species is known from only two specimens which represent the same parts of the animal and no good purpose would be served by erecting a new genus to receive it. Until such time as the species is known from a nearly entire skeleton it should be known as *Camarasaurus agilis* (Marsh).

Camarasaurus supremus Cope 1877

Referred specimen.—No. 467 A.M.N.H., occiput lacking the paroccipital processes, braincase lacking the anterior portion, both pterygoids, right quadrate, part of left quadratojugal, both frontals, right postfrontal, both nasals, both jugals, both maxilla and premaxilla, and both lower jaws.

Locality.—Bone Cabin Quarry, Wyoming. Collected by W. D. Matthew, Expedition of 1899.

Remarks.—In this specimen the sutures between the basioccipital and the basisphenoid and between the basioccipital and the exoccipitals are clearly visible. It is approximately the same age stage as the type of *Camasasaurus grandis* (Marsh). The parts of the braincase preserved agree with those of *C. lentus* (Marsh) and *C. grandis* (Marsh).

Only the anterior half of the pineal fora-

men is preserved but is sufficient to show that the foramen had a diameter equal to that of the foramen magnum.

Apatosaurus ajax Marsh 1877

Type description.—*Apatosaurus ajax* Marsh, O. C., Dec., 1877, Am. Jour. Sci., v. 14, p. 514.

Type material.—No. 1860, Y.P.M., occiput and part of braincase, most of the cervical and dorsal vertebrae, sacrum, ribs, ilium, pubis, both femora, a fibula.

Locality.—Como Bluff, Wyoming.

Referred material.—No. 673, A.M.N.H., occiput, frontal region and braincase from Bone Cabin Quarry, Wyoming. Collected by Walter Granger, Expedition of 1901.

Remarks.—The braincase of the type specimen was figured by Marsh (1896, pl. 15) as *Atlantosaurus montanus* Marsh but in the Catalogue of the Yale Peabody Museum it bears the same number as the type of *Apatosaurus ajax* Marsh. We can only conclude that this was a *lapsis calami* on the part of Marsh.

That both specimens are fully mature if

TEXT-FIG. *1*—Lateral view of the braincase of *Apatosaurus ajax* Marsh, No. 673 A.M.N.H. ×1/2.

not very old invividuals is shown by the complete absence of sutures in the braincase and occiput. The general form of the braincase and occiput shows that this genus, although distinct, is certainly a member of the family Brachiosauridae and is also closely related to *Camarasaurus*.

The differences in the braincase between this genus and *Camarasaurus* are a matter of degree and are difficult to define. The angle between the occiput and frontal region is nearly 90°. The posttemporal fenestra appears to have been triangular in outline with the base of the triangle directed dorsomesially. It is about two thirds the size of the foramen magnum. Although there is considerable damage in the area of the parietal foramen it appears to have had a diameter slightly greater than that of the foramen magnum.

The braincase does not extend anteriorly beyond the posterior border of the orbit (text-fig. 1). The cristae antotica and proötica are damaged in both specimens but as near as they can be interpreted they do not have the extreme development found in *Camarasaurus*. As near as can be determined the cranial foramina agree in detail with *Camarasaurus*.

The tubera basioccipitalia-basipterygoid complex is, on the whole, much more massive than in *Camarasaurus* and is directed posteroventrally rather than ventrally. The tubera are massive and divergent and when viewed from the rear do not appear as though their extremities had been drawn together. The basipterygoid processes are shorter and more massive and are only slightly divergent, not widely so. They are not connected by a wall of bone which extends ventrally to the level of the tips of the tubera. In the specimen in the American Museum (No. 673, A.M.N.H.) there is a deep pit with matrix at the bottom between the tubera basioccipitalia and the basipterygoid processes. This certainly suggests that in this genus the hypophysial fontenelle was open ventrally.

In the type (No. 1860, Y.P.M.) the basipterygoid processes have been broken off exposing the hypophysial fontenelle and the course of the internal carotid. The latter enters the side of the tubera basioccipitalia a little nearer the tip than in *Camarasaurus*. It passes upward and inward to enter the side of the hypophysial fontenelle.

Although both specimens are considerably larger than any known specimen of *Camarasaurus* the actual size of the fenestra ovale is very close to that of the latter genus. We are thus permitted to assume that its hearing was equally good.

The parts of both pterygoids which embrace the recessus basipterygoidens are present in the type. The recess is not so deeply excavated into the bone and the process which clasps the basipterygoid process is represented by a low tubercle.

On the basis of the information furnished by these two specimens it is necessary to remove *Apatosaurus* Marsh from the family Titanosauridae (Romer, 1956, p. 622) and place it in the subfamily Camarasaurinae.

In as far as my present studies have gone the taxonomy of the genus *Camarasaurus* appears to be as follows:

Genus *Camarasaurus* Cope, 1877

Type species.—Camarasaurus supremus Cope. Designated by Mook, 1914, Ann. N. Y. Acad. Sci., v. 24, p. 19.

Type description.—Camarasaurus supremus Cope, E. D., Aug. 1877, Pal. Bull., no. 25, p. 5–10.

Synonyms.—Caulodon Cope, E. D., Nov. 1878, Pal. Bull., no. 28, p. 193–194. Referred: Osborn and Mook, 1921, Mem. Am. Mus. Nat. History, n. ser., v. 3, p. 270.

Morosaurus Marsh, O. C., March 1878, Am. Jour. Sci., v. 15, p. 241. Referred: Mook, 1914, Ann. N. Y. Acad. Sci., v. 24, p. 20.

Uintasaurus Holland, W. J., 1924, Ann. Carnegie Mus., v. 15, p. 119–138. Referred: this paper, p. 478.

Camarasaurus supremus Cope, 1877

Type description.—Camarasaurus supremus Cope, E. D., Aug. 1877, Pal. Bull., no. 25, p. 5–10.

Type material.—No. 5760, A.M.N.H. (Cotypes), one cervical, three dorsal and four caudal vertebrae.

Locality.—Canyon City, Colorado. Collected by O. W. Lucas, 1877.

Synonyms. — Camarasaurus leptodirus Cope, E. D., June, 1879, Am. Nat., v. 13, p. 402–404. Referred: Osborn and Mook,

1921, Mem. Amer. Mus. Nat. History, n. ser., v. 3, p. 268.

Caulodon diversidens Cope, E. D., Nov. 1877, Pal. Bull., no. 26, p. 193–194. Referred: Osborn and Mook, 1921, Mem. Amer. Mus. Nat. History, n. ser., v. 3, p. 270.

Caulodon leptoganus Cope, E. D., Jan. 1878, Pal. Bull., no. 28, p. 247. Referred: Osborn and Mook, 1921, Mem. Amer. Mus. Nat. History, n. ser. v. 3, p. 271.

Apatosaurus grandis Marsh, O. C., Dec. 1877, Am. Jour. Sci., v. 14, p. 515. Referred: this paper, p. 478.

Morosaurus impar Marsh, O. C., March 1878, Am. Jour. Sci., v. 15, p. 241. Referred to *M. grandis* (Marsh): Williston, 1898, Kan. Univ. Quart., v. 7, p. 173.

Morosaurus robustus Marsh, O. C., Nov. 1878, Am. Jour. Sci., v. 16, p. 414. Referred: this paper, p. 479.

Camarasaurus lentus (Marsh) 1889

Type description.—Morosaurus lentus Marsh, O. C., Nov. 1889, Am. Jour. Sci., v. 37, p. 333.

Type material.—No. 1910, Y.P.M., vertebral series from second cervical to eighth caudal, fourth cervical rib, left scapula, part of right coracoid, both humeri, left radius, both ilia, right pubis, left ischium, left femur, both tibia, left hind foot.

Locality.—Como Bluff, Wyoming.

Synonyms.—Uintasaurus douglassi Holland, J. W., 1924, Ann. Carnegie Mus., v. 15, p. 119–138. Referred: this paper, p. 478.

Camarasaurus agilis (Marsh) 1889

Type description.— Morosaurus agilis Marsh, O. C., Apr. 1889, Am. Jour. Sci., v. 37, p. 334.

Type material.—No. 5384, U. S. N. M., occiput and frontal region, braincase, and cervical vertebrae one to three.

Locality.—Canyon City, Colorado.

Synonyms.—None.

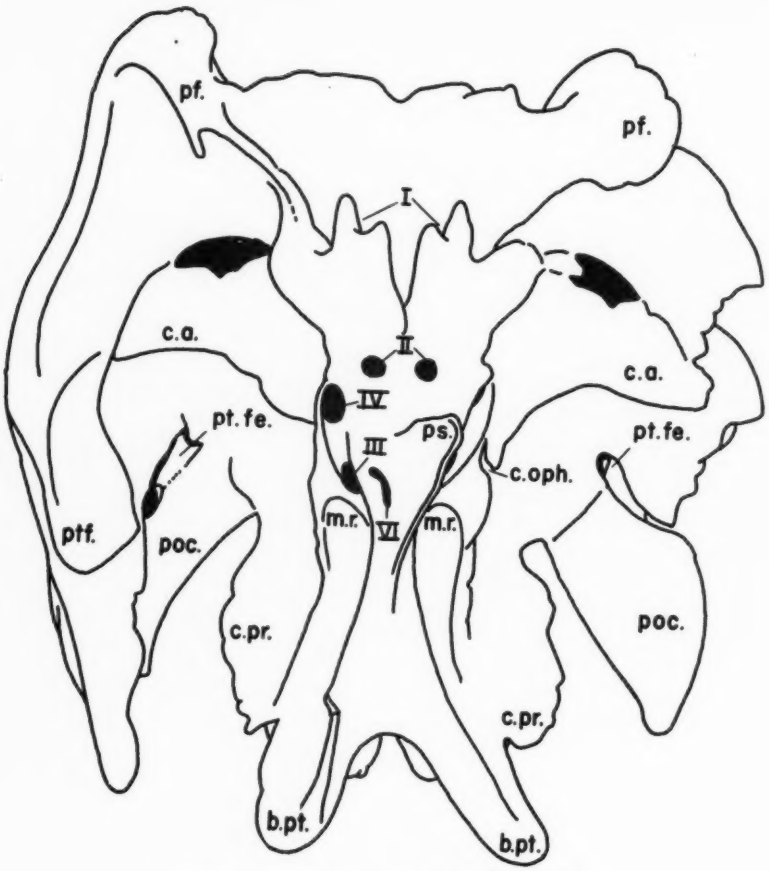
BRAINCASE

The best description and illustrations of the form and external features of the skull of *Camarasaurus* are those of Gilmore (1925) for specimen No. 11,338 in the Carnegie Museum. His illustrations have been reproduced in many standard textbooks.

The present specimen, judging by the breadth across the postfrontals, represents an individual about one-third larger than that studied by Gilmore. The braincase and skull roof have fused into a solid mass of bone in which any trace of most of the sutures has been obliterated. The remaining elements of the skull, except for the lower jaws, have been freed from their neighbors through preburial maceration and provide a number of details of the interior of the skull heretofore unrecorded.

The occiput slopes downward and backward from the frontal region at an angle of about 60° and is of considerable depth. The distance from the bottom of the foramen magnum to the supraoccipital protuberance is only slightly less than that from the protuberance to the anterior end of the frontals along the midline. The brain cavity lies along the anterior side of the occiput and slopes upward to terminate against the frontals just posterior to the midpoint of the orbit. The upward tilt of the braincase appears to be characteristic of the Sauropoda and to a lesser degree also characteristic of the Carnosauria in contrast to the Ornithischia in which the braincase is nearly parallel to the frontal area. The upward tilting of the braincase is quite noticeable in the Triassic prosauropod *Plateosaurus* (von Huene, 1926, pl. 1) but is much more pronounced in all of the upper Jurassic sauropods in which the braincases are known. The preservation of the skull of the lower Cretaceous sauropod *Helopus* does not permit an interpretation of the braincase but from the external contours of the skull the braincase must have stood at nearly right angles to the plane of the tooth row.

The basicranial axis, as projected by a line from the center of the occipital condyle to the tip of the presphenoid rostrum, is subparallel to the plane of the frontal region. The tubera basioccipitalia and the basipterygoid processes project downward and backward from about the midpoint of the axis for a distance equal to two-thirds the length of the axis. The extreme downward production of these processes appears to be characteristic of the Order Saurischia in contrast to the Ornithischia in which these processes have the usual reptilian form. Insofar as the braincases of the Sauropoda are



TEXT-FIG. 2—Key to part of Plate 69 (opposite).

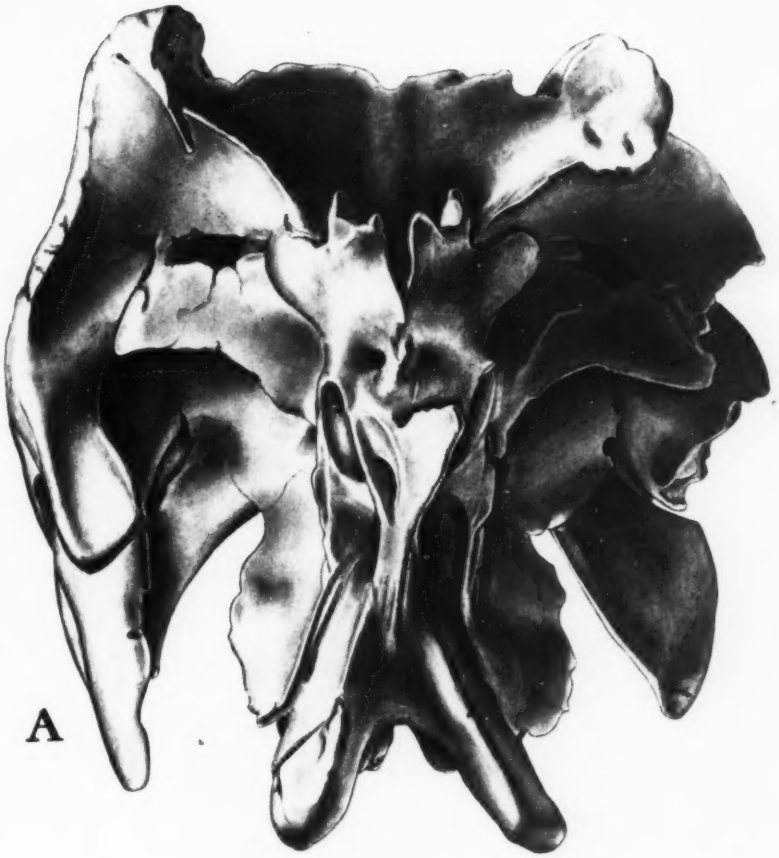
Abbreviations used in text-figures and plates: b. pt.—basipterygoid process of the basisphenoid; c. a.—crista antotica; c. oph.—canal for ophthalmic branch of fifth nerve; c. pr.—crista proötica; d. la.—lachrymal duct; fa. ecpt.—facette for ectopterygoid; fa. pmx.—facette for vomerine process of premaxilla; fe. ep.—fenestra epioptica; f. j.—foramen jugulare; l. pt.—insertion of levator pterygoideus; m. r.—origin of rectus muscles of eye; o. c.—occipital condyle; pf.—prefrontal; p. j.—plaster jacket; poc.—paroccipital process; prt. pt.—insertion of protractor pterygoideus; ps.—presphenoid-parasphenoid; ptf.—postfrontal; pt. fe.—posttemporal fenestra; r. bpt.—recessus basipterygoideus; sq.—squamosal; and t. b.—tubera basioccipitalia.

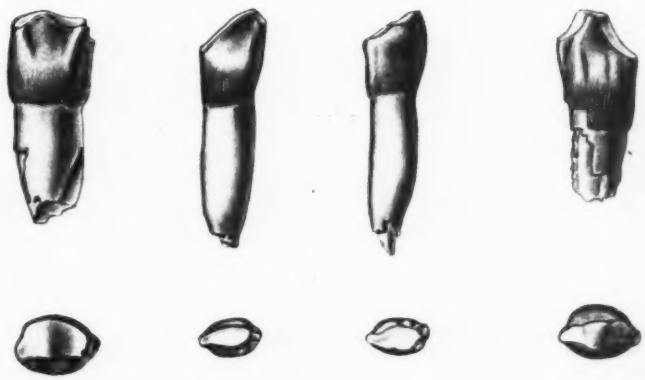
known, the length and general form of these processes agree with the taxonomic grouping of the genera into families and yet are characteristic for each genus. *Brachiosaurus*, *Apatosaurus*, and *Camarasaurus* form one group with strong, robust basipterygoid processes while *Diplodocus*, *Barosaurus*, and *Dicraeosaurus* with slender attenuated processes form another. However, time and space do not permit the presentation of a detailed comparative study of these characters in the *Sauropoda*.

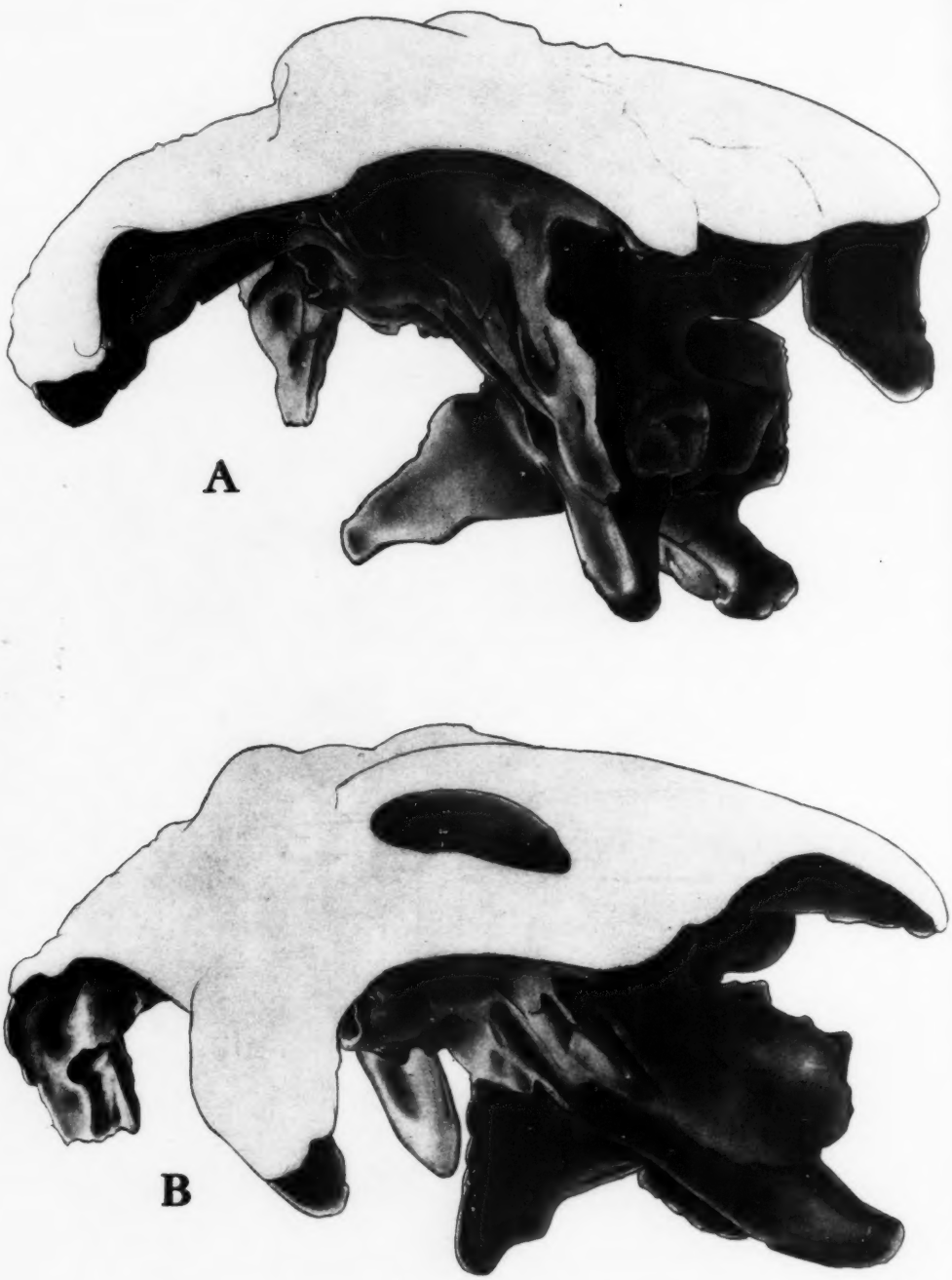
EXPLANATION OF PLATE 69

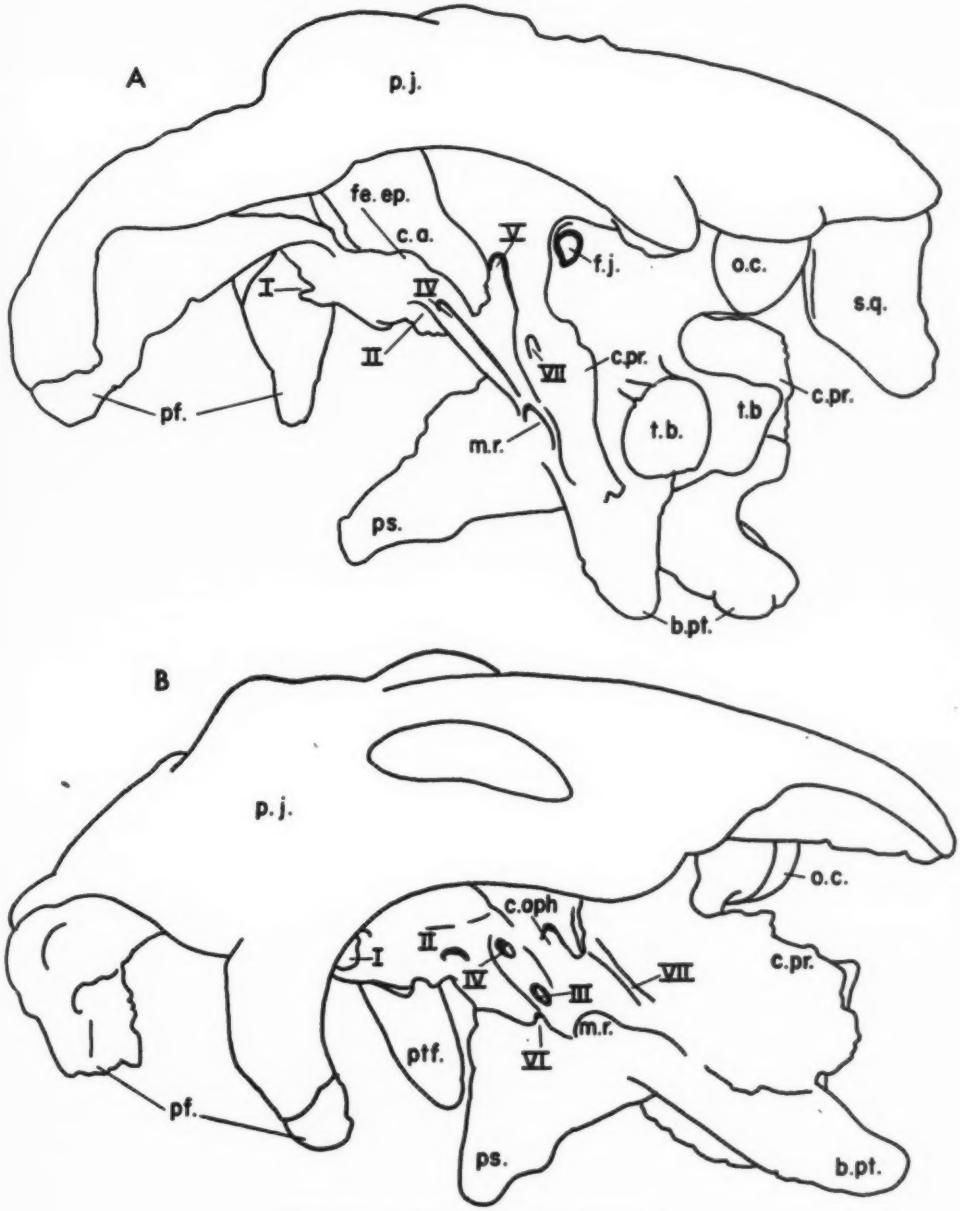
Figures ×0.4

FIG. *A*—Anteroventral view of the braincase of *Camarasaurus lentus* (Marsh).
B—Medial and occlusal views of isolated teeth to show type of wear.


A


B


A
B



TEXT-FIG. *3*—Key to Plate 70 (opposite).

EXPLANATION OF PLATE 70

Figures ×0.4

FIG. *A*—Posterolateral view of the braincase.
B—Anterolateral view of the braincase. In both views the frontal region (at left) is inclined downward to show the foramina better.

Between the condyle and the tubera basioccipitalia the basioccipital is slightly emarginate upward and gives the impression that the condyle is directed downward at nearly right angles with the plane of the teeth. The illusion is heightened by the slope of the occiput and the upward inclination of the braincase. The articular surface of the condyle faces downward and backward. A radius passed through the center of the articular surface makes an angle of about 45° with the plane of the teeth. The angle of the occipital condyle together with the downward curvature of the second and third vertebrae will place the tooth line and face at nearly right angles with the general axis of the neck in the attitude shown by Osborn & Mook (1921, p. 373, fig. 118).

As was stated earlier, the braincase is fused into a solid capsule of bone. The names of the various elements which make up the braincase will be used *only* to indicate the topographic area and in no way indicates that sutures were observed.

Anteriorly the *alisphenoids* (epipterygoids) are united along the midline in their middle and lower portions but the dorsal portions are separated by a narrow V-shaped cleft. There is a rather large semicircular notch for the exit of the olfactory nerve (pl. 69, fig. A) at the upper open end of the cleft. Dorsally the alisphenoids are in contact with the frontals just posterior to the middle of the orbit. The foramen for the exit of the optic nerve and the anterior cerebral artery lies near the midline a short distance below the apex of the cleft between the alisphenoids. Lateral to and only slightly below the optic foramen is the exit of the fourth nerve. The foramen for the exit of the third nerve lies directly below that of the fourth and is approximately the same size but smaller than the optic foramen. Below and just anterior to the oculomotor foramen is a small vertically elongated foramen for the exit of the sixth nerve, the hypophyseal vein and also the palatine artery. Immediately posterior to the foramen for the sixth nerve and below the third is an oval depression 22 mm. long and 16 mm. wide (pl. 69, fig. B). This depression is in the proper location for the origin of the *anterior*, *superior*, *inferior*, and *posterior rectus* muscles of the eye.

Immediately posterior and superior to the trochlear foramen is a narrow, vertically elongated fenestra (*fenestra epioptica*), which is slightly constricted at midlength. The superior and inferior borders are rounded and smooth as though for the passage of a nerve or blood vessel. There is a shallow sulcus extending a short distance dorsally from the upper border and another extends a short distance ventrally from the lower border. From studies on the chondrocrania of lizards, it seems probable that the dorsal sulcus marks the exist of the ophthalmic branch of the internal carotid. The function of the lower sulcus is not obvious from any of the studies on reptilian crania at hand.

Just posterior to the fenestra epioptica the ascending process of the alisphenoid extends upward and outward as a broad lamina of bone (crista antotica) (pl. 69, fig. A) to abut against the postfrontal at the anterolateral margin of the supratemporal fenestra. The crista antotica diminishes in breadth as it passes down the side of the braincase to disappear at the base of the basipterygoid process. On the right side the crista is broadly notched opposite the trochlear foramen by the passage of the ophthalmic branch of the fifth nerve. On the left side the notch is nearly closed over by a spur of bone extending ventrally from the superior border. Just posterior to this notch in the crista antotica is a large foramen for the exit of the fifth cranial nerve. The foramen lies at the bottom of a rather large depression which received the ophthalmic and semilunar ganglia. Two shallow sulci for the maxillary and mandibular branches of the trigeminal nerve pass posteroventrally from the inferior border of the depression.

Below and posterior to the trigeminal foramen is a deep elongate pit at the bottom of which is a foramen for the exit of the seventh nerve. The pit, undoubtedly, enclosed the geniculate ganglion.

Posterior to the foramina for the fifth and seventh nerves is a broad lamina of bone (*crista proötica*), extending from the base of the basipterygoid process to the ventral edge of the paroccipital process. The crista proötica forms the lateral border of a deep recess beside the occipital condyle. Near the dorsal border of this recess is the large oval jugular foramen for the exit of the ninth to

eleventh nerves. The foramen is 20 mm. high and 13 mm. wide. Just anterior to the jugular foramen is the small fenestra ovale, which is 7 mm. high and 4 mm. wide. In size the fenestra ovale in this specimen is proportionately the same as Janensch (1935, p. 262) described for *Brachiosaurus*. For an animal the size of *Camarasaurus* the fenestra ovale is very small and the stapes must have been correspondingly slender and light in weight, capable of being activated by vibrations transmitted through the air, at least those of low frequency. It was not possible to investigate the inner ear in this specimen but in the related form, *Brachiosaurus* (*ibid.*, p. 264), the bony cochlea is a rather short straight tube with the fenestra rotunda opening into the middle ear as in the crocodiles and the birds. It appears then that *Camarasaurus* possessed no obvious morphological handicap to its hearing.

The hypoglossal foramen lies between the foramen jugulare and the foramen magnum. It is nearly circular in outline and has a diameter of 4.5 mm.

The foramen for the entrance of the internal carotid has not been identified with certainty in this specimen. In other sauropods the internal carotid pierces the side of the basicranium between basioccipital and the basisphenoid and passes upward and forward into the hypophyseal fontenelle. In this specimen between the inferior portion of the crista proötica and the side of the tubera basioccipitalia is a matrix filled space about 4 mm. wide. This is the proper location for the internal carotid but preparation was discontinued because of the hardness of the matrix and danger of damage to the specimen.

PALATE

The pterygoids and a single vomer (prevomer) are the only bones of the palate which were recovered. In *Brachiosaurus* the palatines and ectopterygoids are light fragile bones and in this specimen might easily have been carried away by water currents.

The *pterygoid* (pl. 71, figs. A to C) is a triradiate bone which sits nearly vertical in the skull instead of in the more or less horizontal position of most reptiles. The general form of the pterygoid is very similar to that of *Brachiosaurus*. The quadrate process is short and relatively narrow. It is very rugose along the inferior border for the origin of the *pterygomandibularis* muscle. On the dorsal surface near the posterior end is the oval, deeply excavated basipterygoid recess which received the distal end of the basipterygoid process of the basisphenoid. At about the midlength a short stout process arises from the mesial border of the recess and curves posterodorsally around the basipterygoid process. Along the lateral border of the recess is a high thin ridge of bone for the insertion of the *protractor pterygoidens* muscle. The ridge extends from a short distance posterior to the recess to 25 mm. anterior to it. On the lateral surface of the pterygoid, ventral to and anterior to the recess, is a rugose ridge of bone 35 mm. long for the insertion of the *levator pterygoidens* muscle.

The portion of the pterygoid just anterior to the basipterygoid recess is the general center of its triradiate structure. The anterior process is expanded into a broad sheet which is placed vertically near the midline ventromesial to the eyeball. The superior border of this process passes forward and upward ventral to the cranial nerves and eye muscles into the interorbital region. On the mesial side of the anterior ventral angle of this process is a rugose area for the sutural attachment of the vomer.

The sickle-shaped ectopterygoid process curves ventrolatetally from the midportion of the bone. It is almost twice as broad as the same process in *Brachiosaurus*. The anteroventral border is very rugose for the origin of a part of the *pterygomandibularis* muscle. On the mesial side along the anterior portion of the process is a broad shelf to receive the descending flange of the ectopterygoid.

The *vomer* (prevomer) (pl. 70, fig. B) is a narrow thin plate of bone which sits more or less on edge in the skull. The ventral edge is somewhat thickened but the dorsal edge is paper thin. Anteriorly it joins the vomerine process of the premaxilla in an overlapping suture and posteriorly it joins the anterior inferior angle of the anterior process of the pterygoid. With the material at hand, contact with the palatine cannot be demonstrated.

LACHRYMAL

The external features of the lachrymal have been excellently described by Gilmore (1925, p. 358) from specimen No. 11,338 in the Carnegie Museum. Only those features not available to him will be included in the present discussion.

The right lachrymal (pl. 73, figs. B and C) is remarkably entire in view of the thin lamellar bone of which it is constructed. At its inferior end it contacts the maxilla ventrally and the jugal posteriorly. It overlaps the anterior end of the jugal on the medial side.

The upper two-thirds of lachrymal is a thin lamina of bone closely applied to the posterior, medial and anteromedial sides of the upper end of the dorsal process of the maxilla. This gives the bone the appearance in posterior aspect of being very broad transversely and rather robust but actually it is a very thin lamina. From a point opposite the inferior border of the lachrymal foramen the medial edge of this lamina passes forward and downward to blend with the anterior edge of the lachrymal at a point opposite the superior border of lachrymojugal suture.

In this form the lachrymal foramen is a secondary structure and is not the original foramen. The present foramen is a tear-drop shaped opening with a broadly rounded ventral border and with the superior border drawn into a point (pl. 73, fig. B). This appears to have been accomplished by the upward growth of a thin lamina of bone from the inferior border of the lachrymal notch till it met the main part of the bone above the lachrymal duct. In this specimen the lamina has only a sutural union with the main part of the bone above the lachrymal foramen. On the other hand the foramen perforates the bone in *Brachiosaurus* and is elliptical in outline (Janensch, 1935, p. 165).

JUGAL

The jugal is a U-shaped bone (pl. 73, fig. C) with the bottom of the U meeting the lachryma and maxilla. The ventral leg of the U, which lies along the superior border of the quadratojugal and the posterior process of the maxilla, is a thin narrow sliver of bone. The dorsal portion is broad and rather robust.

QUADRATOJUGAL

The quadratojugal (pl. 72, fig. D) is an L-shaped bone with the long leg of the L extending from the maxilla to the quadrate. Anteriorly it unites with the maxilla and anterodorsally with the ventral process of the jugal. The short leg of the L articulates with the lateral surface of the quadrate in a broad overlapping suture. It covers the lower three-fourths of the lateral surface of that bone. In turn the anterior edge of the ascending process of the quadratojugal is overlapped by the descending process of the squamosal.

QUADRATE

Both quadrates (pl. 72, fig. A) are present and had macerated free from the skull before burial. Both are damaged somewhat but they supplement each other so that a fairly reliable concept of the bone can be obtained. In relation to the plane of the teeth the quadrate sits nearly vertical in the skull. The dorsal end at its contact with the squamosal is laterally compressed so that the anteroposterior dimension of the cephalic condyle is nearly three times the lateral. The condyle is broadly rounded both anteroposteriorly and laterally. The mesial portion of the bone is fairly robust and carries the pterygoid process which is a broad rhomboidal sheet of bone. The interior border of the process is robust and carries in its posterior part a rugose area for sutural union with the pterygoid. Above the pterygoid articulation the process is rather thin. The anterior termination of the process is rather robust and is abruptly truncated. Judging by the unfinished surface the process was, undoubtedly, continued forward as cartilage.

The portion of the quadrate which articulates with the quadratojugal and forms the lateral wall of the quadrate fossa is a very thin lamina of bone which extends posterolaterally from the base of the pterygoid process. It extends from the dorsal end of

the quadrate to a point about one-third of the height of the bone above the inferior condyle. The quadrate fossa is an elongate oval depression excavated into the upper two-thirds of the posterior surface of the bone. The depth of the fossa is a little greater than its width.

These are the principal features of the bone not covered by Gilmore's (1925, p. 360) description. The profile of the posterior side of the quadrate in this specimen is only slightly concave while that of *Brachiosaurus* is deeply concave. The pterygoid process has a much greater extent in both height and length in this specimen than in *Brachiosaurus*.

MAXILLA

The external features of the maxilla have been adequately described by Gilmore (1925, p. 362) and will not be repeated here. On the inner surface (pl. 73, fig. C) there was a very limited contact with the bones of the palate. Above the posterior end of the tooth row are two small rugose areas, each not more than 5 or 6 square centimeters for the sutural union with ectopterygoid and palatine. The palatine shelf is restricted to the area above these two sutural areas. The remainder of the buccal area is quite smooth and featureless. On the dorsal side of the palatine shelf and beneath the foot of the lachrymal is the *posterior alveolar foramen* for the maxillary artery and the superior alveolar nerve. Just posterior to this foramen is a short ellipsoidal process which fits into a corresponding recess in the foot of the lachrymal (pl. 73, fig. C).

Above the tooth row is a row of small foramina for the escape of the branches of the maxillary artery and the superior alveolar nerve. The surficial portion of these foramina are elongated anteroposteriorly so that they form a shallow groove which extends the length of the tooth row. The external wall of the tooth row extends ventrally beyond the medial wall for a distance a little greater than the anteroposterior diameter of the socket. This proportion is maintained for the entire length of the tooth row and the actual amount of the extension increases from the back to the front.

PREMAXILLA

The premaxilla and its relation to the maxilla have been adequately described by Gilmore (1925, p. 361) and will not be repeated here.

LOWER JAW

The external features of the lower jaw have been adequately described by Gilmore (p. 363) and will not be repeated here. In this specimen the bones of the medial side of the jaw are missing in both lower jaws. In the specimen of *Camarasaurus* on exhibition (No. 13786) in the United States National Museum, the medial side of one lower jaw is partially exposed. In as far as it can be determined the relationship of the angular, surangular, splenial and dentary in this form differ from that of *Brachiosaurus* (Janensch, 1935, p. 174) only in minor details. Neither on this specimen nor on the specimens in the American Museum of Natural History (Nos. 657, 467, and 5761) could any trace of a distinct coronoid be found.

Two of the lower jaws in the American Museum (Nos. 657 and 5761) show the splenial extending forward as a small sliver of bone on the ventromesial side of the dentary to take part in the symphysis. The symphyseal portion of the splenial is considerably expanded.

In specimen No. 467 in the American Museum the articular is preserved in both lower jaws. It is an elongate mass of bone roughly triangular in cross-section fitting into the recess formed by the angular and surangular. The retroarticular process is rather short, its length being equal to the width of the articular. The ridge of bone, characteristic of carnivorous reptiles, separating the quadrate articulation from the retroarticular process is absent. The quadrate articulation slopes ventromesially from the lateral edge matching the slope of the articular condyle of the quadrate. The quadrate articulation forms a very shallow depression with a broad anteroposterior extent. Thus it is seen that the quadrate-lower jaw articulation is one which will permit considerable movement both laterally

and in anteroposterior direction. Although it cannot be demonstrated that *Camarasaurus* chewed its food by lateral movements of the jaws in the manner of herbivorous mammals the quadrate-lower jaw articulation shows that such a movement was mechanically possible and the type of wear of the teeth (pl. 69, fig. B) indicates that such a movement was highly probable.

TEETH

The high crowned spatulate teeth of *Camarasaurus* are well described and figured in the literature. Their general form and rugose enamel appear to be characteristic of the family but there is not sufficient material at my disposal to attempt to characterize the genera on the teeth.

There are 4 teeth in the premaxilla and 10 in the maxilla making a total of 14 which gradually decrease in size from front to back. The anterior and posterior edges of the teeth exhibit certain extremely smooth areas similar to those found on the corresponding edges of the teeth of herbivorous mammals. This fact is interpreted to indicate that each tooth was closely adpressed against its fellow so that the complete battery of teeth presented a continuous cutting edge for cropping vegetation. The teeth recovered show many stages of wear, from only a slight amount to a condition in which a little over half of the crown is worn away. Examination of the worn surfaces under a dissecting microscope failed to reveal any striations to indicate the mode of chewing. On the other hand, the teeth of herbivorous mammals examined at the same time also failed to reveal any striations on the worn surface.

The left maxilla and premaxilla are still united and contain all of the teeth except the fourth premaxillary and the tenth maxillary (pl. 71, fig. D). Both functional and replacing teeth are represented in the series. The functional teeth exhibit many stages of wear from a negligible amount on the first maxillary tooth to the extreme condition found in the second maxillary tooth in which a little over half of the crown is worn away. During the act of cropping vegetation the teeth in the front of the jaw would receive more strenuous use than those at the back of the jaw. The difference in use would in part be offset by the size of the teeth so that the amount of wear should be a reasonably reliable expression of the relative age of the individual tooth. On this premise it is proposed to examine the teeth of this specimen for whatever information it can provide on tooth replacement in sauropod dinosaurs.

It is common knowledge that the teeth of most reptiles, early amphibians and many fish are repeatedly replaced throughout the lifetime of the individual. Individual teeth are usually missing in a number of places along the jaw and those adjacent to the gaps exhibit various stages of growth or resorption of the roots. When the complete series of teeth are available it is seen that the order of replacement travels as a wave along the jaw. This phenomenon has become known as a *replacement wave*. It is also evident that several waves are traveling along the jaw at the same time. However, a critical examination of the teeth present in the jaw in view of their relative stage of growth or resorption of the roots shows that this concept, while a step in the right direction, falls short of a complete explanation.

As early as 1896 attempts were made to solve this riddle and a number of very worthwhile contributions have been made since then. An excellent summary of the present state of our knowledge and a pertinent bibliography is to be found in the "Osteology of the Reptiles" by Professor A. S. Romer. A comprehensive study of tooth replacement in reptiles both fossil and recent is being prepared by Mr. Gordon Edmond of the Royal Ontario Museum for his doctoral dissertation.

The several studies on this subject indicate that there are actually two sets of teeth present in each jaw—each set represented by alternate teeth. One view is that each set of teeth has its own set of replacement waves which operate independent of each other. Romer refers to the two sets of teeth as *odds* and *evens* according to whether their number in the complete series is odd or even when numbered from the front of the jaw.

For the purpose of this study it is necessary to establish a set of arbitrary symbols to represent the amount of wear on a tooth and another to represent the stage of growth of the replacement tooth.

Set A. Amount of Wear.

Number 1 represents a functional tooth with a negligible amount of wear.

Numbers 2 to 6 represent successive stages of wear. Number 6 represents the most extreme case of wear.

Set B. Replacement Teeth.

R_1 represents a replacement tooth, the tip of which is even with or just below the inner rim of the socket.

R_3 represents a tooth which will soon become functional.

Using these sets of arbitrary symbols the upper teeth of the left side of this specimen can be represented by the following block diagram:

	Front				Back									
Odd	R_2		1		1		2		3		4		R_3	
Even		3		0		6		5		R_3		2		R_1
	Premaxilla				Maxilla									

An examination of the above diagram shows that in the even series there is in the premaxilla a tooth showing moderate wear and an empty socket. In the maxilla the first tooth has the greatest amount of wear and is hence the oldest tooth of the series. The second tooth of the series has less wear and is, therefore, younger. The third tooth is a replacement tooth while the fourth shows a small amount of wear. The last tooth is a replacement tooth just appearing in the socket and is the youngest of the series. On the basis of this data it would appear that at the time of death of the specimen the latest replacement wave had reached the second premaxillary tooth and was traveling from *front* to *back*.

In the odd series the first premaxillary tooth is a replacement tooth. The second premaxillary and first maxillary have very recently become functional as the amount of wear is negligible. The next three maxillary teeth show increasing amounts of wear with the fourth showing the greatest wear. Consequently, the fourth maxillary tooth is the oldest of the series. The fifth maxillary tooth is a replacement tooth which would soon have become functional. It would appear then that in the odd series with the oldest teeth at the back of the series the replacement wave travels from *back* to *front*.

The third maxillary tooth of the even series represents an anomalous condition for which there is no ready explanation. On the basis of the above interpretation, it should have had a wear value of 4 or 3 but such was not the case.

Since the replacement waves of the odds and evens travel in opposite directions, it is inevitable that they should meet and the replacement order for both sets would coincide in that particular area of the jaw. This appears to explain the occurrence, especially in jaws with very long tooth rows, of short series composed of relatively new teeth of both sets and of other short series in which the roots of the teeth of both sets are in various stages of resorption.

With only a single specimen at hand, it is impossible to be certain that the replacement waves travel across the suture between the maxilla and premaxilla but such appears to be the case. This is to be expected since both are supplied by the same blood vessels and enervated by the same nerves.

Camarasaurus has a short tooth row considering the reptiles as a group but it appears that in each set a new replacement wave has started before the old one has completely traversed the length of the jaw. On this basis then jaws with a very long tooth row should have several replacement waves traveling along the tooth series at the same time.

The teeth were missing from both lower jaws in this specimen. In the specimen on exhibition in the United States National Museum, the jaws are closed so that the tips of the lower teeth cannot be seen. The same is true of the specimen in the Carnegie Museum described by Gilmore (1925). Consequently, it is impossible to determine whether or not the replacement waves move

in the same directions in the lower jaw with respect to the odds and evens that they do in the upper. Janensch (1935, pl. 10) published photographs of the lower dentitions of *Brachiosaurus* at his disposal but highlights make evaluation of the amount of wear very difficult. In as far as the teeth of *Brachiosaurus* can be evaluated from the illustrations according to the arbitrary criteria I have set up the direction of movement of the replacement waves is the same in the lower jaw with respect to the odds and evens as it is in the upper.

Janensch (*ibid.*, p. 209) concluded that Woerderman's thesis of alternate sets of teeth in each jaw is not applicable to the Sauropoda because a smooth rhythm to the order of replacement is lacking if both replacement waves travel from front to back. On this basis he concludes that the teeth of the Sauropoda represent a single series. However, a smooth rhythm in the order of replacement is not shown by his diagrams (p. 207). In the specimen under consideration here a smooth rhythm was obtained neither by considering the entire series as a single set nor by postulating that the replacement waves of alternate sets moved in the same direction. In this specimen a reasonably smooth rhythm in the order of tooth replacement is obtained only if one considers that the replacement waves of alternate sets move in opposite directions.

The teeth were firmly implanted in the jaw by conical roots approximately two and one-half times the height of the crown. Each isolated tooth recovered exhibits a thin layer of cement (about 0.2 mm. thick) covering the root but it does not appear to overlap onto the base of the enamel. The cement is deposited on the roots of teeth by the *alveolar periosticum* of the tooth socket and in addition this tissue securely binds the root of the tooth to the wall of the socket. The presence of cement on the roots of the teeth of *Camarasaurus* shows that the teeth were secured to the jaw in the same manner as the teeth of mammals, i.e., through the medium of the alveolar periosticum. This is probably also true of most thecodont reptiles as well.

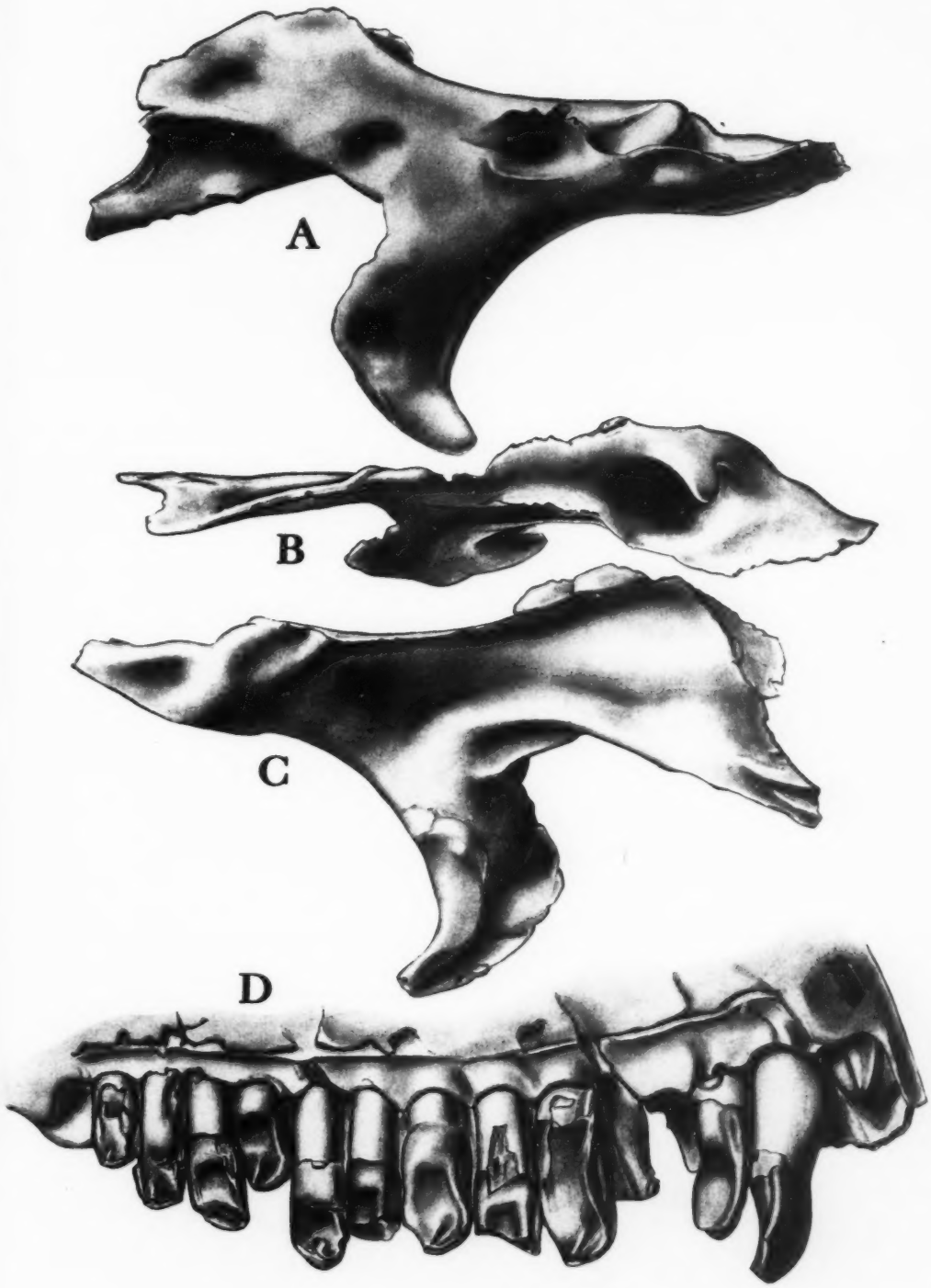
On those isolated teeth recovered in which the root was nearly complete a characteristic *resorption crescent* is present on the medial side of the tip of the root. An examination of the anterior end of the right maxilla (pl. 73, fig. A) shows a replacement tooth not yet functional and another behind it in the socket in an advanced state of development. This poses the question of whether, in long rooted thecodont teeth such as these, the crescent represents actual resorption or rather the cession of growth from lack of space. In the case of acrodont and pleurodont teeth the tooth is secured to the jaw by the growth of bony material around the base of the tooth and resorption of this material is essential before the tooth can be dropped from the jaw. In the case of thecodont teeth the root is securely bound to the walls of the socket by the alveolar periosticum and this tissue must be temporarily broken down before the tooth can be dropped from the jaw. Partial resorption of the root may also take place coincidental with the temporary breakdown of the alveolar periosticum but from the physiological viewpoint is not essential in dropping the tooth from the jaw.

There is a difference in the type of wear of teeth between *Camarasaurus* and *Brachiosaurus*. In *Camarasaurus* the teeth wear straight across while in *Brachiosaurus* the upper teeth are beveled off on the inside and the lowers on the outside so that the worn teeth present chisel edges which, in a sense, are self-sharpening.

EXPLANATION OF PLATE 71

Figures ×0.4

FIGS. *A–D*—Left pterygoid. *A*, lateral; *B*, dorsal; and *C*, medial views. *D*, upper dentition of left side, medial view.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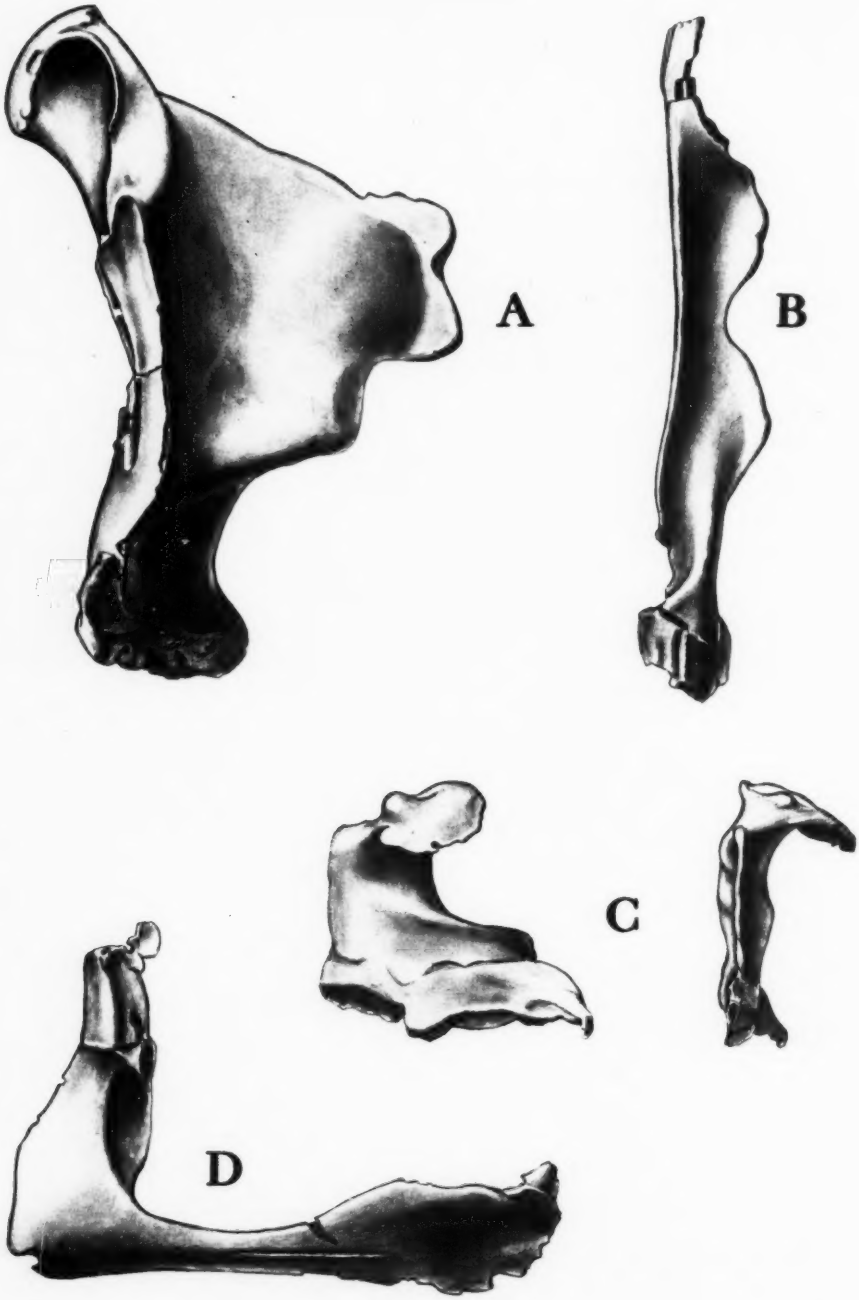
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EXPLANATION OF PLATE 72

Figures ×0.4

FIG. *A*—Right quadrate, lateral view.
B—Left vomer, lateral view.
C—Unidentified bone, possibly proatlas, medial and posterior views.
D—Right quadratojugal, lateral view.

Cope: Mem. Am. Mus. Nat. History, n. ser., v. 3, p. 249–387, pls. 60–85.

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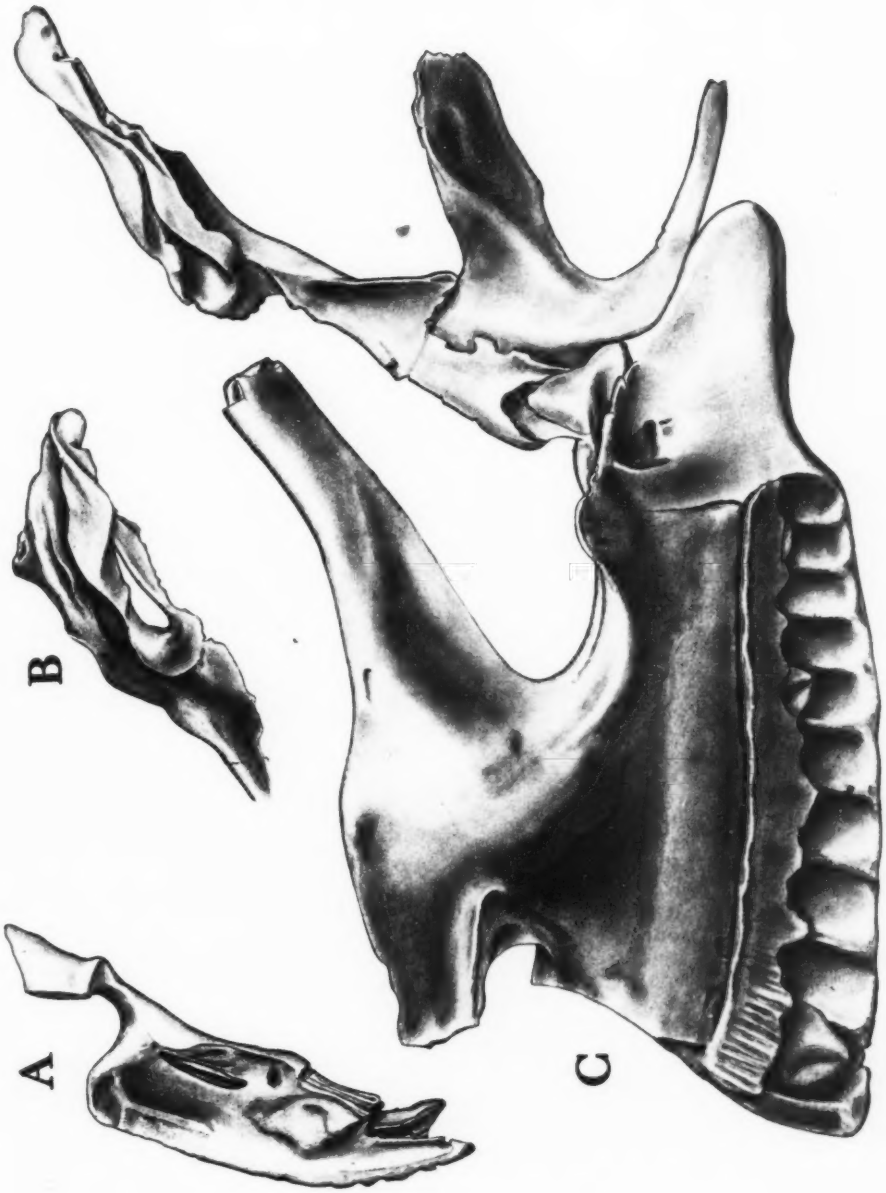
MANUSCRIPT RECEIVED APRIL 15, 1957.

EXPLANATION OF PLATE 73

Figures ×0.4

FIG. *A*—Anterior end of right maxilla showing tooth replacement.
B—Anterior view of right lachrymal showing foramen.
C—Right Maxilla, jugal and lachrymal, medial view.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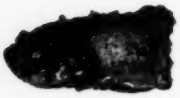

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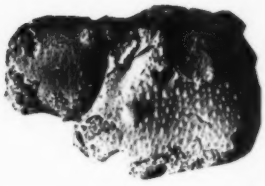

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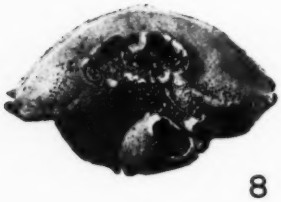

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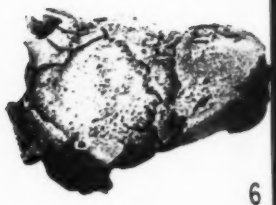

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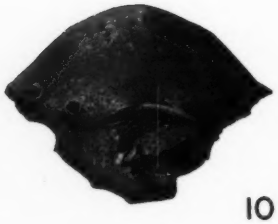

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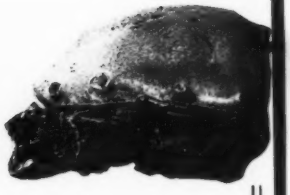

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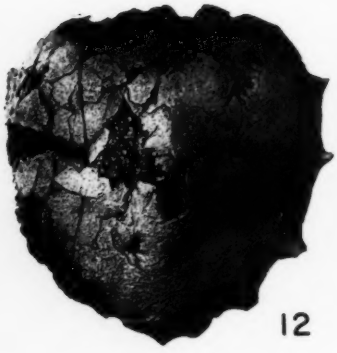

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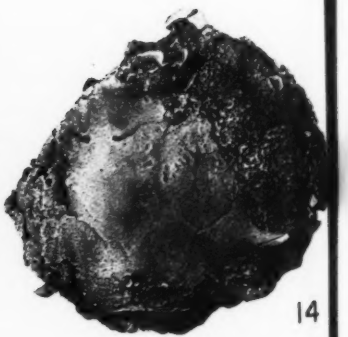

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 495–505, PL. 74, 3 TEXT-FIGS., MAY 1958

CRABS FROM THE CANNONBALL FORMATION (PALEOCENE) OF NORTH DAKOTA[1]

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University of North Dakota, Grand Forks

ABSTRACT—More than 50 specimens of fossil crabs collected from the Cannonball formation (Paleocene) of southern Morton and Burleigh Counties, south-central North Dakota form the basis for the first report of fossil crustaceans in North Dakota. The new genus *Camarocarcinus* is created for their reception with the new species *C. arnesoni* as the type species. A separate, single, large propodus is placed in a new species, *Ranina* (?) *burleighensis*, by the senior author. The mode of occurrence suggests a near-shore condition of the Cannonball sea in this part of North Dakota.

INTRODUCTION

THE rarity of fossil decapod crustaceans in the northern Midcontinent makes the recent discovery of over 50 specimens of well preserved fossil crabs in the Cannonball formation of south-central North Dakota the more interesting. These are the first fossil crabs to be found in North Dakota, and prior to this find only six species in as many genera were known from this general area (Rathbun, 1935). The following decapods have previously been reported by her from the northern Midcontinent:

South Dakota
Pierre Shale:
Dakoticancer overana Rathbun; west side Missouri River, in Corson Co. a short distance south of Mobridge; and along Indian Creek, Pennington Co.
Necrocarcinus pierrensis Rathbun; eastern Corson Co.
Homolopsis punctata Rathbun; eastern Corson Co.
Callianassa cheyennensis Rathbun; both banks of Missouri River between the Cheyenne

[1] Published by permission of the State Geologist of North Dakota.

[2] Formerly Fulbright Scholar, University of New England, Armidale, New South Wales; currently U.S. Air Force.

EXPLANATION OF PLATE 74

All figures ×1

FIGS. *1–14*—*Camarocarcinus arnesoni* Holland & Cvancara, n. gen., n. sp., Cannonball formation, Paleocene, Locality No. 1, southern Burleigh County, North Dakota. All specimens believed to be female. *1,2*—Respectively outer and inner views of right manus with carpus attached at nearly right angle to observer; dactylus and pollex missing. Paratype, UND No. 574. *3,4*—Respectively outer and inner views of broken left propodus of paratype, UND No. 573. *5*—Ventral surface showing inflated pterygostomium with rim (near right exognath), third maxilliped with left endognath pushed under curved exognath, broken merus, carpus, and propodus with partial pollex and dactylus of right cheliped rotated posteriorly 180° out of natural position, and stubs of two ambulatory legs of left side. Paratype, UND No. 573. *6*—Left lateral view of crushed specimen to illustrate the rostrum. Hypotype, UND No. 705. *7–11*—Respectively dorsal, anterior, ventral, posterior, and right lateral views of holotype, U. S. Natl. Mus. No. 562093. Dark irregular spaced marks especially evident in Figs. 7 and 8 are pocking of the exoskeleton by weathering. Fig. 9 shows the distally broken right manus and complete carpus on viewer's left; near the posterior the left ischiobasis, merus, and propodus are shown. Fig. 10 shows a portion of the carpus articulated with the propodus of the left cheliped. Fig. 11 shows the rostrum to the viewer's right and the broken rim of the carapace just below the large lateral spine bases. *12,13*—Dorsal and ventral views respectively of large, fractured specimen. Paratype, UND No. 572. *14*—Dorsal view of badly broken specimen showing long, curved right fourth lateral spine. Paratype, UND No. 571.

15—*Ranina* (?) *burleighensis* Holland, n. sp., Cannonball formation, Paleocene, Locality No. 1, southern Burleigh County, North Dakota. Outer view of left propodus showing broken dactylus and stub of pollex. Holotype, U. S. Natl. Mus. No. 562094.

River and the North Dakota-South Dakota line.
Niobrara formation:
Linuparus canadensis (Whiteaves); head of Cottonwood Creek, Meade Co.
Carlile shale:
Linuparus canadensis (Whiteaves); near Whitewood, Lawrence Co.
Wyoming
Lewis shale:
Tetracarcinus subquadratus Weller; on U. S. Highway 30, 8 miles west of Rawlins, Carbon Co.

All of these species are from the Upper Cretaceous; and except for *Dakoticancer overana*, which is represented by more than 80 specimens in the original collection (Rathbun, 1917), each is known from only one or two specimens from this area. In addition *Necrocarcinus pierrensis* and *Tetracarcinus subquadratus* are known from New Jersey, *Dakoticancer overana* from New Jersey and Tennessee, and *Linuparus canadensis* has been taken from the Benton group of Alberta and identified by Rathbun from the Ripley formation of Tennessee and Louisiana. The collection of fossil crabs at hand, then, is the first known to the writers from the Tertiary of the north-central States and the Prairie Provinces.

Mr. William W. Arneson (now geologist, Northwest Geological Service, Billings, Montana, but then serving as Field Inspector and Geologist for the Conservation Division of the North Dakota Geological Survey) made the initial collection of eight rather complete carapaces, numerous fragments, and associated material in early November, 1954. During June, 1955, the writers visited the site of the original discovery numerous times and subsequently the site has been revisited several times by both Mr. Arneson and the senior author. The collection has been added to on each occasion until at this time it consists of over 50 well-preserved and fairly well-preserved carapaces, and numerous fragmental or badly weathered carapaces and separate partial pereiopods.

The specimens collected are apparently heretofore undescribed and a new genus, *Camarocarcinus* and two new species are created for their reception. The crustacean fauna of the Cannonball formation thus consists of:

Camarocarcinus arnesoni Holland & Cvancara, n. gen., n. sp.
Ranina (?) *burleighensis* Holland, n. sp. (one specimen only).

Since the original discovery at Locality No. 1, below, crabs have been found by the writers at two additional localities in the Cannonball. Cannonball crab localities in North Dakota (Fig. 1) are:

Locality No. 1—Sand blow-out, west side of road, NE corner, Sec. 28, T. 137 N., R. 77 W., 5 miles west and 1.1 miles south from Moffit, southern Burleigh Co., North Dakota.

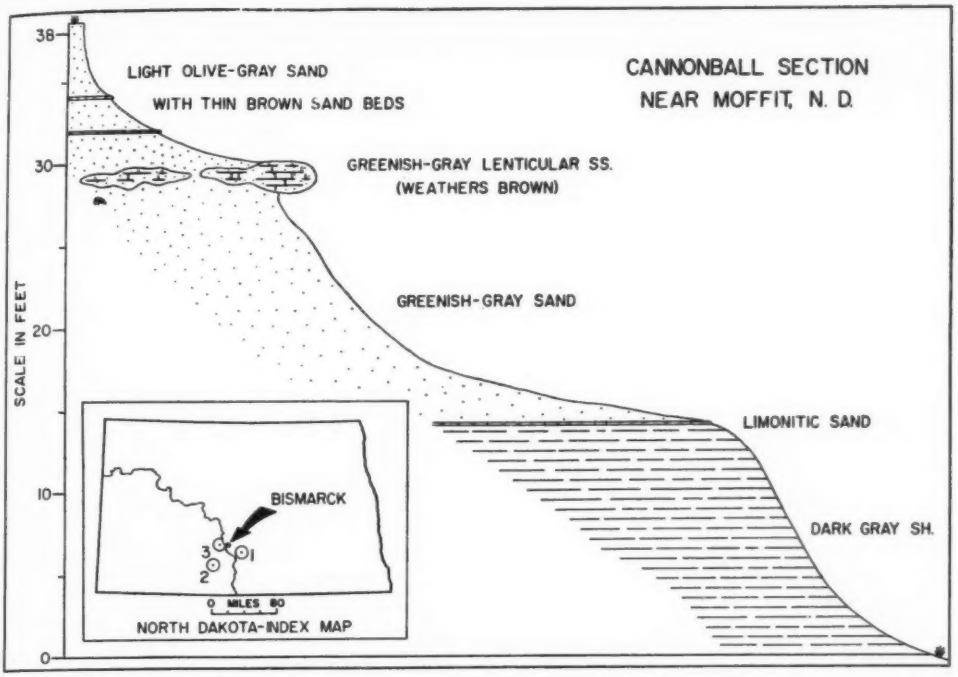
Locality No. 1a—Just south of crest of hill, curve in abandoned road east of new road, NW ¼ Sec. 28, T. 137 N., R. 77 W., 6 miles west and 1.1 miles south from Moffit, southern Burleigh Co., North Dakota.

Locality No. 2—South facing hillside, north of North Dakota highway 21, NW ¼ Sec. 4, T. 134 N., R. 83 W., about 5 miles east of Flasher, Morton Co., North Dakota.

At Locality No. 1 the crabs were found weathered out and lying loose on the surface, especially near the upper part of the exposed section, while at Localities 1a and 2 they were laboriously cracked from extremely hard sandstone nodules. At Locality No. 1a these nodules were strewn down the hill on the surface of the old road, but at Locality No. 2 the nodules were found loose in the grass below obscure sandstone outcrops.

Stratigraphy.—Maps by Lloyd and Hares (1915), Stanton (1920), Hansen (1952, 1956), and Benson (1951) show the areal extent of the Cannonball formation in North Dakota. Laird and Mitchell (1942) and Fisher (1952) have presented measured sections of the Cannonball in Morton County and in Emmons County (east of the Missouri River just south of Burleigh County); and for more details of the regional stratigraphy of the general area, the reader is referred to these publications. For faunal information on the Cannonball one should refer to papers by Stanton (1920), Vaughan (1920), Fox and Ross (1942), and Brown and Lemke (1948).

Localities 1 and 1a occur in an area shown on these maps as being the continental Hell Creek formation of Upper Cretaceous age. However the Cannonball seems to be more extensive east of the Missouri River than was previously suspected. East of the river



TEXT-FIG. *1*—Section of Paleocene Cannonball formation in road-ditch exposure, Locality No. 1, near Moffit, southern Burleigh County, North Dakota. This is the type locality of *Camarocarcinus arnesoni* Holland & Cvancara, n. gen. n. sp., and *Ranina* (?) *burleighensis* Holland, n. sp.; the crabs were found free, loose on the surface, mostly near the upper part (31 to 35 feet above base of measured section) of the exposure. The insert map shows the two principal areas where *Camarocarcinus* occurs (Locality 1a is only one mile west of Locality 1 and hence these two localities are covered by dot of No. 1).

in southern Burleigh and northern Emmons Counties the Cannonball comes to lie directly on the Hell Creek (Fisher, 1952, p. 20, 41), but in Morton County, west of the Missouri River, the continental facies equivalent of the Cannonball, the Ludlow formation, interfingers with it, and a tongue of the Ludlow reaches east to the bluffs of the Missouri below the Cannonball, separating it from the underlying Hell Creek (Laird and Mitchell, 1942, p. 18).

It is entirely possible that the claystone at the bottom of the exposed section is Hell Creek, for Hell Creek was found some 65 feet lower, one mile east and .9 mile south of this locality (SW¼ Sec. 26, T. 137 N., R. 77 W.).

At Locality 1a the section is mostly covered but some light olive gray sand could be seen in gullies beside the old road (later completely filled in when a new road was built during July 1956) north of the crest of the hill. At the very crest of the hill a three-inch sandstone very similar to that of the crab matrix occurs, but no crabs or crab-bearing nodules could be found in place.

At Locality 2 in Morton County nodules bearing crabs and crab fragments were rather common about the level of the sub-upland (Number 2) bench or middle Cannonball sand of Laird & Mitchell (1942, p. 19). The nodules are commonly three to four inches in diameter and subspherical or elongate with the general shape commonly controlled by vague harder sandstone "tubes" which traverse the interior of the nodule. These tubes (generally about one half inch in diameter) are irregular in their occurrence and architecture and seemingly have no direct connection with the crabs

SECTION MEASURED AT LOCALITY NO. 1

(Colors according to Goddard, et al., 1948)

	Feet
Sand dunes; grass	
Sand; light olive-gray (5Y 6/2), fine grained, subangular to angular, with occasional thin irregular beds of light brown (5YR 5/6) very fine grained, hard sandstone or moderate brown (5YR 3/4) fine grained, semiconsolidated sandstone	8.4
Sandstone; greenish gray (5GY 6/1), fine grained, subangular, calcareous, very hard lenticular; weathers moderate yellowish brown (10YR 6/4)	2.0
Sand; light olive-gray (5Y 5/2) becoming slightly darker near base; fine grained to very fine grained, angular to subangular; few very thin limonitic, semiconsolidated sandstone beds and nodules; many vertical "worm" tubes of yellowish gray sand near top; petrified wood bored by shipworms abundant on surface	13.9
Sand; limonitic semiconsolidated, containing small fragments of light olive gray shale	.2
Claystone; olive gray (5Y 4/1) to light olive gray (5Y 6/1), blocky, nonfissile, containing triturated plant material; few thin limonitic silt to very fine sand beds near top	14.1
Total exposed section	38.6

which occur in the nodules; their origin remains an enigma.

The lithology of the matrix covering the ventral surface of the crabs from Locality 1 and the lithology of the nodules which contain crabs at Localities 1a and 2 is so distinctive that the writers can ascertain almost every time which nodules will contain a carapace or crab fragments. At another locality (herein called Locality No. 3) the writers, however, found nodules believed identical to those of Localities 1a and 2 but could find no crabs.[3] Locality No. 3 is:

Top of road cut, north side U. S. highway 10, SE¼ Sec. 23, T. 139 N., R. 82 W., 4.65 miles west of railway station, center of Mandan, Morton County.

The junior author made a quantitative petrographic study of the nodules with the results shown in Table 1 (percentages estimated with the use of charts in Spock, 1953, p. 28–31).

The matrix of the crabs at Locality 1a might thus be more exactly designated a grayish brown (5YR 4/2) phosphatic feldspathic arenite, and the nodules from the other localities would be phosphatic subfeldspathic lithic arenites (according to the terminology of Williams, Turner, and Gilbert, 1955). The cement of all of the nodules seems to be collophane and dahllite.

Associated with the crabs at Locality 1 were the following fosssils: Abundant petrified wood much of it bored by a *Martesia*-like pelecypod, *Lamna cuspidata* Agassiz (shark teeth), and shark (?) vertebrae. A small *Protocardia*-like pelecypod was found in a nodule at Locality 1a. Tiny gastropods (? *Drepanochilus* sp.) were found in a nodule at Locality 3; fish scales and bones, fossil wood, pelecypods (*Lucina cedrensis* Stanton and *Trigonocallista* sp.) and gastropods were found in a similar rock on Mitchell Butte, two miles southwest of Locality 2, although crabs were not found on Mitchell Butte.

Paleoecology.—The writers envision a shallow epicontinental sea (although not as restricted as formerly thought, Brown and Lemke, 1948, and Hansen, 1956) and a mild climate in central North Dakota in early Paleocene time. It is believed that *Camarocarcinus* inhabited the littoral or epineritic zone and burrowed in the sand as described

[3] Since the manuscript for this paper was prepared, Mr. Arneson has found nodules of "crab lithology" containing fragments of *Camarocarcinus* in a roadcut on the south side of U. S. highway 10 about one mile west of Locality 3 on a hillside at the same level as Locality 3. Thus, following the discovery of nodules of this distinctive lithology and futile search for crabs by the writers, the prediction that crabs would be found in the vicinity has been borne out. This locality (designated Locality 3a) makes the fourth site from which *Camarocarcinus* has been collected.

TABLE 1—PERCENTAGES OF VARIOUS COMPONENTS IN CANNONBALL SANDSTONE NODULES

Locality	Feldspar	Quartz	Cement	Rock fragments	Other Minerals	Void pores
1a	15%	20%	43%	12%	4%	6%
2	15%	15%	40%	23%	3%	4%
3	10%	20%	35%	21%	4%	10%

by Bourne (1922) for many of the Raninidae. How efficient a digger was *Camarocarcinus* can not be estimated, for the distal portions of the posterior pereiopods are unknown. Since the body of this form is not as elongated as many of the raninids, it may not have lain deeply buried but may have been adept at natation. In any event, shifting sands may have overwhelmed many of the crabs in their burrows, for it is believed that most of the crabs were not washed about as empty carapaces so perfect is the preservation. The association with large logs of fossil wood, the abundant borings in the wood, the sharks' teeth and bone fragments, and the absence of normal marine shells, even the very appearance of the outcrop at Locality 1, suggests an ancient beach with its scattered driftwood, sand bars, and polished pebbles.

Acknowledgments.—The writers are indebted to many people for aid during the preparation of this paper. To these people we extend our grateful thanks. We are especially indebted to William Arneson for his geological alertness in discovering these unusual fossils in an inauspicious looking sand blow-out while working in a different capacity for the State Geological Survey. He recognized the type of animal represented, and, realizing their relative rarity and value, has generously presented his entire collection to the Geology Department, University of North Dakota. We wish to thank Dr. Wilson M. Laird, State Geologist of North Dakota, for providing the opportunity and facilities for field and laboratory study in connection with this description. Dr. H. B. Stenzel of Houston, Texas, and Dr. Fenner A. Chace, Jr., U. S. National Museum, have been kind enough to criticize the manuscript and offer many helpful suggestions. Miss Caroline G. Lybeck, Assistant Librarian of the University of North Dakota, has been most co-operative throughout the study. Dr. D. J. Georgacas, Department of Modern and Classical Languages, University of North Dakota, graciously assisted the writers with the etymology of the names involved. Messrs. R. G. Monroe and E. E. Wilson aided the writers in the field. Dr. and Mrs. G. C. Wheeler, Biology Department, University of North Dakota, and son, Ralph, have donated specimens collected by them and have maintained an enthusiastic interest in the study.

SYSTEMATIC PALEONTOLOGY

Phylum ARTHROPODA Siebold & Stannius, 1845
Class CRUSTACEA Pennant, 1777
Order DECAPODA Latreille, 1802
Suborder HETEROCHELIDA Beurlen & Glaessner, 1931
Tribe BRACHYURIDEA Glaessner, 1929
Superfamily GYMNOPLEURA Bourne, 1922
Family RANINIDAE Dana, 1849
Genus CAMAROCARCINUS, n. gen.

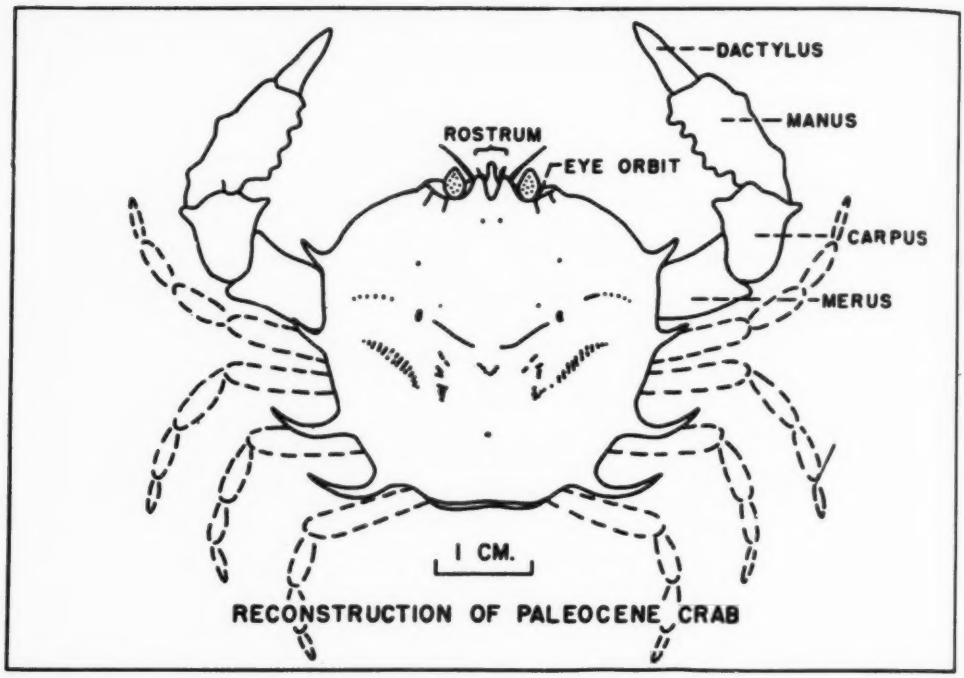
Type species.—*Camarocarcinus arnesoni* Holland & Cvancara, sp. nov.

Etymology.—*καμάρα* (camara) f., vault; plus *καρκίνος* (carcinus) m., crab.

Description.—The generic characters are inextricably bound up with the specific characters until other species are discovered and described. Likely to be distinctive of the genus, however, are such characters as the broadly obovate, strongly arched carapace; the narrow trifid rostrum between deep-set lateroventrally slanted orbits; the four strong postero-lateral spines; and the laterally flattened spinose propodus.

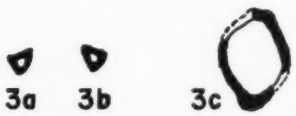
CAMAROCARCINUS ARNEOSONI n. sp.
Pl. 74, figs. 1–14; text-figs. 2,3a,3b.

Description.—Carapace broadly obovate, only slightly longer than wide; strongly arched both transversely and longitudinally; greatest width well anterior to midlength; fronto-orbital width about 2/5 that of the carapace; four prominent spines on postero-lateral margin. Longitudinal curvature of carapace at midline gradual from rostrum to a position posterior to midlength and then dropping sharply to truncated posterior margin; transverse curvature more even throughout, slightly less towards lateral margins and greatest near midline. Antero-lateral margins evenly but strongly rounded from lateral edges of orbit to first lateral spine; postero-lateral margin gently curving to truncated posterior; postero-lateral margin about twice the length of antero-lateral margin. Rostrum trifid with lower upwardly curved medial point (rostrum proper) extending forward beyond



TEXT-FIG. *2*—Diagrammatic scale reconstruction of *Camarocarcinus arnesoni* Holland & Cvancara, n. gen., n. sp. Dashed lines hypothetical and the eyes, antennae, and antennules are completely hypothetical. The merus (?) of one ambulatory leg is known, but it is more slender than any shown here. The carpi of the chelipeds are shown rotated rather too far inward and the meri are a bit heavy. The chelipeds were likely carried folded closely in against the front of the body. The round axial posterior dot indicates the position of the cardiac node; the other marks indicate indentations of the exoskeleton.

orbits; paired lateral points or supra-orbital spines prominent and extending forward horizontally, not curved. Orbits deep-set, oval, about 1.5 times as wide as high, long dimension slanted downward and outward at about 45° angle; lateral margins of orbits marked by heavy, pronounced, lateral spines; upper orbital margin flaring slightly upward and outward and bearing two distinct fisures. Antero-lateral margin set with low irregular granules; postero-lateral margins each set with four discrete, sharp-pointed spines. The anterior spine is nearly triangular with the apex directed anteriorly and upward, the second spine is slightly longer, more slender, very sharp and curved upward and anteriorly; the third, removed approximately the same distance from the second as the second is from the first, is longer, more curved, and shaped like the posterior spine; the latter is set near the posterior margin at a lesser distance from the third spine than separates the others, and is long, horn-like, and strongly curved upward and anteriorly.



TEXT-FIG. *3*—Transverse section (×1) through dactyli of Cannonball crabs as viewed from anterior. *3a,3b, Camarocarcinus arnesoni* Holland & Cvancara, n. gen., n. sp., section about 2 mm. anterior to junction of dactylus and manus; *3a*, right dactylus UND 693; *3b*, left dactylus UND 573; *3c, Ranina* (?) *burleighensis* Holland, n.sp., left dactylus (holotype, USNM 562094) section through first prehensile tooth; dotted lines indicate where exoskeletal material is missing.

Surface of carapace completely and regularly marked with circular (presumably

setiferous) various-sized pits which bear either elevated or depressed rims of darker exoskeletal material. Bodily regions, in general, poorly defined. A broad poorly defined axial ridge is discernible; this ridge commonly bears a marked cardiac aerolation, and the branchial regions are usually swollen. The cervical groove consists medially of a pair of short posteriorly arcuate grooves ending toward the center in a pair of deeper indentations on either side of the midline; these grooves make an obtuse angle of about 120°. Antero-laterally beyond this inner part is a deep, large, subcircular pit; still beyond is an outer curved part of the cervical groove, consisting of a row of faint coalescing pits, which terminates near the lateral margin between the first and second spine. Cardiac grooves indefinite, merely a series of pits; from the posterior end of these a semi-lunar line of muscle imprints curves forward toward the second spine; from the anterior end an indistinct V-shaped series of muscle imprints crosses the axial ridge. Within the anterior half of the carapace on each side of the axial ridge are several pits: one about 3 mm. inward and forward of the large pit which interrupts the cervical groove, another larger pit about 5 mm directly anterior of the large pit of the cervical groove, and a pair just posterior to the rostrum. A low but distinct rim is rolled up at the posterior margin of the carapace.

Chelipeds about equal in size or right slightly larger than left. Coxa unknown; basis fused to ischium although juncture is visible; basio-ischium short and smooth, slightly swollen distally; merus long, moderately heavy, essentially smooth but with fine spinules throughout length along outer lower edge. Carpus distinctive, short, inflated laterally, rounded proximally, triangular distally when viewed from the side. The rounded proximal portion overlaps the merus in a depressed articulation furrow while the distal triangular part greatly overlaps the manus on its upper surface; a short heavy spine is borne at each angle of the triangle of the carpus. Manus elongated, laterally compressed, inner surface smooth and nearly flat, outer surface inflated and turberculate, upper surface nearly flat or slightly rounded, inferior surface rounded or slightly keeled distally; thus in cross-section the manus is subtriangular. The upper surface of the manus bears a row of tubercles and spinules on its inner margin; there is also a posteriorly directed tubercle on the upper surface where the apex of the distal triangular end of the carpus articulates with the manus; outer surface marked by two spinules, the distal one conical, the proximal one double, with a low ridge between them; lower margin of manus bearing eight to twelve irregularly spaced spine bases; all surfaces granular and pitted except inner surface which is commonly quite polished. Pollex deflected sharply downward, otherwise unknown. Dactylus apparently short, tapering rapidly (extremity unknown), subtriangular in transverse section; upper surface flat, keeled on inner and outer edges; granular and pitted on upper and outer surface; prehensile teeth lacking or unknown.

Ambulatory legs virtually unknown; first two apparently unequal in size; one dissociated leg is long, thin, laterally crushed, with merus (?) bearing spine bases on lower (?) margin.

Third maxillipeds relatively slender but inflated (at least posteriorly) bearing granules and smaller setiferous pits on outer surface; exognath nearly as heavy as endognath but more curved; exognath tapering anteriorly. Coxa of third maxillipeds inflated; basis of endognath fused to ischium but suture depressed and readily visible; ischium long, flattened or slightly inflated; merus long, thin, flat, and sharply deflected dorsally (usually fractured) at junction with ischium extending far forward to base of antennules just beneath rostrum; palp unknown. Anterior sternal segment apparently indented by a notch at posterior edge. Broken stubs of antennules located close together just below rostrum even with lower margin of orbits; antennule stubs oval and marked by pits which were apparently setiferous.

Pterygostomial region inflated especially anteriorly; densely covered with setiferous pits; interior edge of pterygostomium with reflexed rim.

Abdominal segments smooth, or minutely granulose, shiny, transversely arched, with a broad raised axial region, and on each side

of this a raised lateral region; each segment save the terminal segment bears a transversely elongate median spine or tubercle and two smaller lateral tubercles, one on each lateral region. Terminal segment broad, flat, ovate with median ridge set with two transverse nodes. Genital openings unknown.

Measurements.—All measurements were made in millimeters according to the prescription of Rathbun (1918, p. 9, or 1930, p. 4). Where two sets of numbers are given for segments of chelipeds, the upper set indicates the right cheliped.

lected by W. W. Arneson, F. D. Holland, Jr., A. M. Cvancara, and R. G. Monroe.

Horizon and type locality.—Cannonball formation, Paleocene; loose on surface approximately 6 feet below top of exposure; sand blow-out, ditch west side of road, N. E. Corner Sec. 28, T. 137 N., R. 77 W., 5 miles west and 1.1 miles south of Moffit, Burleigh Co., North Dakota (Locality No. 1).

Discussion.—Although many morphological features of this species are well-preserved and clear, certain of the critical major characters, such as the genital openings and thoracic sterna, are obscured; thus

No.	Carapace		Fronto-Orbital Width	Rostrum		Cheliped					
	Length	Width		L.	W.	Merus		Carpus		Manus	
USNM 562093	37.4	35.4	13.2	4.1	6.1	—	—	—	—	11.4	7.4
						—	—	10.2	8.4	12.0	7.5
UND 572	42+	42.8	—	—	—	—	—	—	—	—	—
UND 573	—	33.3	12.0	—	—	—	6.1	9.8	7.3	9.8	6.5
						—	—	—	—	—	6.3
UND 574	—	—	—	—	—	—	—	—	8.0	13.1	7.4
						—	—	—	—	—	—
UND 705	?34	?38+	?13.6	5.5	7+	—	—	—	—	—	—
						—	—	—	—	—	—
UND 575	35+	36.2	13.8	—		—	—	—	—	—	—
						—	—	—	—	—	—
UND 717	—	39.9	—	—		—	6.0	—	—	—	—
						—	—	—	—	—	—

Types.—Holotype: U. S. National Museum No. 562093. All other types are in the University of North Dakota collections. Paratypes: UND 571 (partial dorsal carapace in matrix); UND 572 (large fractured carapace with abdomen also preserved); UND 573 (carapace with left propodus separate); UND 574 (right carpus and manus); UND 575 (carapace with abdomen; unfigured); UND 691 (badly broken carapace but with excellent left third maxilliped; unfigured). Figured hypotypes: UND 705 (badly crushed dorsal carapace); UND 693 (partial carapace with well preserved right carpus and propodus). Col-

its affinities are not clear. The genus has been tentatively placed in the Raninidae but this is open to serious question. Regarding the Gymnopleura Roger (1953, p. 350) says, "Ce sont les *Raninidae* de Dana et formes voisines, que l'ornementation chagrinée et la contour de la carapace caractérisent suffisamment." However, he makes no attempt to break down this superfamily. Rathbun (1926, p. 89) characterizes the Raninidae as having the anterior thoracic sterna broad, the posterior thoracic sterna narrow and keel-like, female genital openings on the coxae, last pair of pereiopods dorsal, thoracic nerve ganglion-chain elon-

gate, antennary sternum triangular, and eight branchiae on each side. None of Rathbun's criteria is discernible on *Camarocarcinus*. The shagreen ornamentation mentioned by Roger is present, but the shape is not raninoid since *Camarocarcinus* lacks the wide toothed front and carapace which tapers posteriorly.

Markings of the dorsal surface are strikingly reminiscent of *Notopocorystes dichrous* Stenzel (Stenzel, 1945, p. 439; compare Text-fig. 2 with Stenzel's Fig. 13). The cervical grooves have approximately the same weight, the two close-set indentations posterior to the rostrum (tip of mesogastric region) are similar; and while the cardiac grooves of *Notopocorystes* are much deeper, the whole pattern of branchiocardiac grooves are not dissimilar.

The strongly convex carapace, the poorly defined body regions, and the spines situated so far posterior call to mind the Leucosiidae (cf. *Persephona*). Yet here again, one is frustrated by preservation, for this family is characterized by the hard hemispherical carapace and by having the branchial openings situated on either side of the mouth at the bases of the third maxillipeds. However in the Oxystomata (the superfamily here concerned), the buccal framework is triangular, but it is not in *Camarocarcinus*.[4]

Although the systematic position is thus left in doubt, several morphological details admit discussion. Apparently the outer mouth parts, or third maxillipeds, were particularly robust, for the preservation of these structures is truly amazing. Although not all of the features herein described were preserved on any one specimen, the various segments were in general well preserved whenever the ventral surface could be seen, and the sutures and articulations were clearly visible. Usually both the endognath and exognath appear somewhat flattened rather than inflated. How much of this is natural and how much is due to compression is not known; the merus at least seems to be naturally flat; the inflated, rounded character becomes more apparent posteriorly on the other segments.

One of the most immediately striking features is the surface ornamentation. Of the observable portions none seems to be entirely free of the crateriform pits. The pterygostomium is less densely covered than is the dorsal surface, and on the anterior of the pterygostomium anteriorly directed granules partially replace the pits; the pits, however, are present between these granules although they become finer posteriorly. The outer and under surface of the pereiopods, although not generally as well preserved as other parts of the organism, seem to be nearly free of the pits. The upper surface of the manus and dactyli of the chelipeds are densely covered, however, The abdomen is virtually free of minute ornamentation although tiny crateriform pits appear near the lateral boundaries of the abdominal segments. On the third maxillipeds the pits are very tiny and lack the rim so that the maxillipeds appear much smoother than most of the surface.

Withers (1927, p. 178–179) described and illustrated the surface of *Ranina trechmanni* and Stenzel (1945) has compared this with *Notopocorystes dichrous* Stenzel. The surface of both of these is marked by pits and flattened granules "which are so closely set that the interspaces are mere chinks" (Stenzel, p. 440). This is not true in *Camarocarcinus;* nor are the pits arranged in circlets, and they never intersect as in *Ranina trechmanni* (Withers, p. 129, Fig. 1). Each pit is a discrete entity, with a raised rim, the center filled with a white calcareous (?) clay-sized matrix, and with a pore piercing the exact center. On broken edges and in thin sections these pores are seen to penetrate the several exoskeletal layers. The crateriform pits are of two or three orders of size, but the smaller pits are irregularly placed throughout and not grouped around the primary pits; some minute granules of a fourth order in size are present. Over the whole dorsal surface, in the interspaces between the pits, runs an irregular anastomosing set of faint, tiny grooves. The major indentations that form the muscle imprints are devoid of pits. Since these pits appear to bear pores, and since many (at least the the larger pores) are seen to penetrate to the

[4] The suggestion of Dr. Chace that, based on shape of the carapace, *Camarocarcinus* be placed "near the atelecyclids such as *Pliosoma*, *Corystoides*, and *Bellia*" (letter to senior author dated April 26, 1957) merits serious consideration; yet there are objections to this systematic placement.

inner surface these are interpreted by the writers as having been setiferous. If that be true, *Camarocarcinus* was hirsute indeed! The hairs were undoubtedly of survival value in filtering the sand as described by Bourne (1922) and Borradaile (1922); the clogging of the hairs of the ventral surface by a too rapid influx of sand likely caused the demise of the creatures.

As preserved, the holotype is dusky brown (5 YR 2/2) to brownish black (5 YR 2/1), but other specimens range from these colors to grayish brown (5 YR 3/2) or brownish gray (5 YR 4/1). Most of the specimens are of the darker values with the pereiopods still darker; however the white filling in the pits tends to make the exoskeletal material appear deceptively light in value when viewed casually.

The species is named in honor of the finder and donor of the original specimens, Mr. William W. Arneson.

Genus RANINA Lamarck, 1801

RANINA (?) BURLEIGHENSIS Holland, n. sp.
Pl. 74, fig. 15; text-fig. 3c.

While making the final study of crab fragments from Locality No. 1, the senior author discovered a single fragmental left propodus of a seemingly raninoid crab. Since this specimen appears to be entirely different from *Camarocarcinus*, and since the junior author has not had an opportunity to study the specimen, the senior author accepts full responsibility for the new species here proposed.

Description.—The holotype (only known specimen) is black and consists of the broken distal portion (two-thirds ?) of the left manus, the stub of the pollex or immovable finger, and the proximal part of the dactylus of a rather large propodus. The manus, though laterally crushed, appears to have been oblong in cross-section with the width about three-fourths the height. The outer surface of the manus is covered with irregularly spaced, asymmetrical tubercles which are inclined forward. Between the tubercles are smaller, more symmetrical, rounded granules. Inner surface similar but with the tubercles less pronounced. The tubercles apparently disappear toward the upper surface and on the pollex. On upper distal corners of the manus near the articulation of the dactylus is situated a pair of spine bases. The base of a single, small, forward-directed spine can still be seen on the outer surface near the junction with the pollex.

The dactylus is so broken that it is impossible to determine its length. On the inferior surface a rounded projection appears near the break, 6.5 mm. anterior to the junction with the manus; this projection is presumed to be the first prehensile tooth. The section shown as Text-fig. 3c is drawn through this tooth, and the measurements of the dactylus given below were made at this position. At this place the dactylus is subovate but it expands rapidly in a proximal direction and becomes flatter on the superior surface.

Posteriorly directed projections occur on the upper proximal corners of the dactylus; the projections apparently articulated with poorly preserved sockets in the upper distal corners of the manus. A spine base of an anteriorly directed spine is borne on the distal edge of each projection (the inner spine was observed by the writer but broke during preparation). The dactylus is covered with irregularly spaced shallow pits.

Although little remains of the pollex, it appears almost rectangular in cross-section, pitted like the dactylus, and inclined downward from the manus.

Measurements.—All measurements were made in millimeters according to the prescription of Rathbun (1918, p. 8); see also Menzies (1951, p. 169).

	Measured	Estimated
Manus		
length	16.8	29.0
height	22.4	24.0
width	18.0	18.5
Dactylus		
length	13.2	?
height	13.3	13.3
width	9.2	9.2
Pollex		
length	4.5	?
height	?	6.3
width	15.0	15.0

Type.—Holotype (only specimen): U. S. National Museum No. 562094.

Horizon and type locality.—Cannonball formation, Paleocene; loose on surface approximately 6 feet below top of exposure; sand blow-out, ditch west side of road, NE corner Sec. 28, T. 137 N., R. 77 W., 5 miles

west and 1.1 miles south of Moffit, Burleigh County, North Dakota (Locality No. 1).

Discussion.—The generic assignment is made with considerable misgivings, yet the downward deflection of the pollex, the flattened upper surface of the dactylus (and presumably the manus), and the granulose ornamentation is reminiscent of raninids. However, the large size militates against this assignment; but no other generic assignment is apparent to the writer.

The specific name is derived from Burleigh County, North Dakota.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 506–516, PLS. 75–77, 1 TEXT-FIG., MAY 1958

PROUINTATHERIUM, NEW UINTATHERE GENUS, EARLIEST EOCENE, HOBACK FORMATION, WYOMING, AND THE PHYLOGENY OF DINOCERATA

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ABSTRACT—The genotype, *Prouintatherium hobackensis*, most closely resembles *Probathyopsis successor* Jepsen among the Paleocene and early Eocene uintatheres. However, in some aspects it has progressed toward such middle Eocene forms as *Uintatherium* Leidy and *Elachoceras* Scott, particularly in the development of a deep and abrupt lower jaw flange and loss of rotational mobility of the lower forelimb. Sexual dimorphism is well developed. It is concluded that this new genus represents the most direct link yet discovered between *Probathyopsis* and the middle Eocene uintatheres. *Bathyopsoides* Patterson and *Bathyopsis* Cope are considered divergent from the main line of uintathere evolution, suggesting a wider degree of radiation than was previously indicated for the Dinocerata.

INTRODUCTION

In January, 1952 (Dorr, p. 89) I briefly announced the discovery of some of the uintathere materials upon which this study is based. I collected additional specimens from the same locality during the summers of 1951, 1952, and 1953, so that more of the skeleton of the mammal to be described is now represented. Study of the whole of this material leads me to believe that I was in error in assigning the original specimens to *Probathyopsis successor* Jepsen and that they should be described as new. This study also leads to certain conclusions concerning the phylogeny of the Dinocerata.

ACKNOWLEDGMENTS

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STRATIGRAPHIC OCCURRENCE AND FAUNAL RELATIONSHIPS

All of the uintathere materials to be described came from a single quarry in the Hoback formation. The University of Michigan designation for this locality is UM-Sub-Wy Loc. 7. The age of the rocks at the quarry level is Wasatchian, and probably earliest Eocene (very early Wasatchian –lower Graybull) but may be latest Paleocene–Clarkforkian. The limited faunal evidence now available is not conclusive. The quarry is located in the N.E.¼ sec. 16, T. 38 N., R. 113 W., Sublette Co., central western Wyoming (Hoback River Basin). The Hoback formation is at least 15,000 feet thick. The rocks at the quarry level lie 3100–4100 feet below the uppermost exposed part of that formation, about 1600 feet below UM-Sub-Wy Loc. 2 (early? Wasatchian–Graybull equivalent) and about 3000 feet above UM-Sub-Wy Loc. 1 (late Paleocene–Tiffanian), all in the same formation. Fossil vertebrates previously reported from Loc. 7 (Dorr, 1952) are: *Coryphodon* sp. [near *C. testis* (Cope)], and *Probathyopsis successor* (based upon the materials to be described and reassigned in

this paper). Waterworn fragments of large turtles are common in the vicinity and at the level of the quarry. A few internal molds of gastropods were found in the quarry matrix. A partial lower jaw of *Phenacodus* (cf. *P. primaevus* Matthew) was recently found near the quarry but in rocks about 150 feet stratigraphically below those at quarry level. All specimens from this locality are catalogued and stored in the University of Michigan Museum of Paleontology (UMMP). The rocks at the quarry level are probably slightly older than those at UM-Sub-Wy Loc. 2 (Graybull equivalent) and are definitely younger than those at UM-Sub-Wy Loc. 1 (Tiffanian). No latest Paleocene–Clarkforkian faunal levels have been identified with certainty in the Hoback formation but that time interval must be represented somewhere within the strata below Loc. 7 (the quarry) and above Loc. 1. The rocks at localities 1, 7 and 2 are part of a continous lithologic sequence within which no disconformities have been recognized. So far no lithologic continuity has been found between strata at any level in the Hoback formation and rocks outside the Hoback Basin.

NATURE AND EXTENT OF FOSSIL MATERIAL

The fossil remains recovered from the quarry include parts of two individuals of the genus *Coryphodon* and portions of at least four individual uintatheres. The specimens were removed from a matrix of dark brown, silty shale. Ironstone concretions were especially abundant near and against the bones. The skeletal parts of the individual animals were dissociated, completely intermingled, in some instances badly crushed or broken, and often waterworn to varying degrees. The quarry extended about fifteen feet along the strike of the outcrop and an equal distance into the steeply sloping hillside down the gentle dip of the strata. Quarrying was discontinued partly because the depth of overburden had become too great for hand removal, but also because it had become apparent that the principal level of bone concentration had been passed. The mode of occurrence made it impossible to determine the proper association of the various skeletal elements from their juxtaposition in the quarry. Such information was kept but proved to bear little relationship to the kinds or sizes of the individual animals involved. However, the remains of *Coryphodon* were clearly distinguished by their greater size from those of the uintatheres. Faced with the problem of cataloguing the uintathere material, I elected to first sort it as far as possible on the bases of sex, size, canine and related jaw structure, and degree of tooth wear, into one or another of four groups, the minimum number of individuals represented by left third upper molars. I grouped the remaining uintathere materials that were of more uncertain individual affinity according to their position in the skeleton (teeth, limbs, vertebrae) and assigned those groups separate catalogue numbers. No doubt some errors of personal judgment crept into the results of this sorting procedure, but I do not believe they have seriously affected the conclusions based upon the whole of the material. In particular, the decision to sort whenever possible according to sex was based upon studies that preceded actual sorting on that basis. The alternatives, one catalogue number for all specimens, or separate numbers for each piece, would have been impractical or would have tended to obscure certain important relationships.

TAXONOMY

Class MAMMALIA
Order DINOCERATA
Family UINTATHERIIDAE

PROUINTATHERIUM, n. gen.

Genotype.—Prouintatherium hobackensis, n. sp.

Generic diagnosis and definition.—Small sized, about as in *Probathyopsis successor* Jepsen; markedly smaller than *Bathyopsis* Cope, *Bathyopsoides* Patterson, *Elachoceras* Scott, or *Uintatherium* Leidy; slightly larger than *Probathyopsis praecursor* Simpson or *P. newbilli* Patterson. Sexually dimorphic; males larger than females. Dentition complete except for upper incisors and P_1^1. Upper canines long rooted, curved, triangular in cross-section, sharply pointed and edged, much enlarged in males, less enlarged in females. Other dental features alike in sexes except for size. Lower canines larger than incisors. Lower jaw deeply flanged in males, probably less so in females.

Flange in males terminates abruptly beneath P_4 posteriorly and is clearly distinct from horizontal ramus of mandible, as in *Elachoceras* and *Uintatherium*, not as in *Bathyopsoides* or *Bathyopsis*. Angle of mandible with strong externoventral deflection, heavily ridged, dropping abruptly below ventral margin of mandible about as in *U. segne* Marsh. Mandibular symphysis deeper and longer than in *Probathyopsis;* ventral margin V-shaped. Lower incisors as in *Probathyopsis successor* but with single or double lingual ridge and strong external (posterior) heels. Canine-premolar diastema almost as long relative to cheek tooth row as in *Bathyopsoides* or *Bathyopsis:* shorter than in *Uintatherium*. Talonid crests long as in *Probathyopsis*, not as compressed as those of *Bathyopsoides*. Entoconid distinct from hypoconulid. Metastylid weaker than in *Probathyopsis* or *Bathyopsoides*. P^2 with very weak posterior transverse ridge in unworn teeth; ectoloph set at less than 45 degrees to cheek tooth row. Metacones indicated but not rising above ectoloph. Upper molars lack parastyles. Cingula incomplete at bases of protocones, *not* as in *Probathyopsis*, even less complete than in *Bathyopsoides*. M_1^1 much smaller than M_2^2, slightly smaller than P_4^4 but, in size, seemingly a member of the premolar series. Maxillary horns probably present above roots of upper canines. A prominent, overhanging maxillary shelf and fossa above cheek teeth, as in *Uintatherium*. Anterior thoracic vertebrae with relatively long, slender neural spines. Humerus short, triangular in central cross-section, strongly ridged and rugose, but not tuberculated. Radius and ulna indicating strong ligamentary connection. Olecranon process in line with long axis of ulna, not posteriorly deflected. Phalanges short, small, dorsoventrally flattened. Distal phalanges very rugose.

PROUINTATHERIUM HOBACKENSIS, n. sp.
Pls. 75–77

Probathyopsis successor Jepsen, DORR, 1952, Geol. Soc. America Bull., v. 63, p. 72,89.

Type specimens.—The following lists will be of aid to those who may later wish to study the specimens upon which the species is based. I believe that the individual animals represented by these specimens all were members of a single population. Therefore, regardless of the fact that certain of the specimens are selected as "types," the whole of the material constitutes the sample from which the inferences concerning generic and specific characters were drawn:

Holotype, male, UMMP 27249, large adult. Nearly complete left lower jaw with P_3–M_3. Three fragments of large upper canines. Two large lower canines. RP^2, RP^3, LP^3, RM^1, LM^2 and LM^3, all isolated. One mandibular condyle fragment.

Paratype, female, UMMP 27250, small adult. Left lower jaw with M_2; anterior part and coronoid process missing. Right lower jaw with M_3; anterior part and coronoid process missing. Right maxillary fragment with P^2–M^3. Two relatively small upper canines, one lacking root. One small lower canine lacking root and tip. RP_2, RP_4, LM^2, LM^3, all isolated.

UMMP 27251, female, small adult. Left maxillary fragment with M^{1-3}. Small upper canine lacking root, RP^2, RM^3 fragment, LP_3, LM_2, LM_3, all isolated.

UMMP 27252, female (?), small adult. One LM^3.

Paratype, sex (?), UMMP 27523, relative size (?). Atlas, lacking all of transverse processes but roots. One anterior thoracic vertebra with neural spine. One neural spine of an anterior thoracic vertebra.

EXPLANATION OF PLATE 75

All figures approximately $\times \frac{1}{2}$

FIGS. *1–7*—*Prouintatherium hobackensis*, n. gen. and n. sp. University of Michigan Museum of Paleontology catalogue numbers. *1–3*, holotype, 27249, adult male; left lower jaw with P_3–M_3, lingual, labial and occlusal views, respectively. *4–7*, paratype, 27250, adult female. *4*, left lower jaw with M_2. *5–7*, right maxillary fragment with P^2–M^3, occlusal, labial and lingual views, respectively.

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Paratype, sex (?), UMMP 27254, relative size (?). Nine isolated lower incisors whose wide range of size variation probably reflects both position in the tooth row and size variation in two or more individuals.

Paratype, sex (?), UMMP 34122, young adults, large. *Not* certainly all parts of one individual. One femur, crushed, lacking proximal end. One left humerus, nearly complete, lacking proximal end and part of distal articulation surface. Two ulnas, left and right, nearly complete. One left radius, lacking distal epiphysis. (The humerus, left ulna and radius mentioned above articulate nicely and are very probably parts of one individual.) One distal fragment of humerus with articulation surface nearly complete. Two scapular fragments, lacking blades and spines, but with glenoid surfaces intact. One astragalus, left, very large, may be from a small *Coryphodon*. Twelve phalanges (3 distal; 2 of the 12, including 1 distal, were found in association in the matrix with the crown portion of one of the upper canines catalogued as UMMP 27249).

UMMP 34123. Uintathere fragments and fragments of questionable uintatherian affinity. 11 foot bones, 3 humeri, 3 radii, 1 large ulna, 1 small ulna.

Horizon and type locality.—Earliest Eocene, early Wasatchian–Graybull equivalent (probably early Graybull), Hoback formation, University of Michigan UM-Sub-Wy Loc. 7, N.E.$\frac{1}{4}$ sec. 16, T. 38 N., R. 113 W., Sublette Co., Hoback River Basin, central western Wyoming (see Dorr, 1952).

Diagnosis and definition.—So far the sole species assigned to the genus. Generic and specific characters inseparable at present. Trivial name derived from the Hoback River Basin type locality and the Hoback formation.

Description and comparisons.—The lower jaw in this species has two anterior mental foramina placed about midway between the diastemal border and the lower edge of the flange, and $\frac{1}{3}$ and $\frac{1}{2}$ the diastemal length behind the posterior margin of the canine alveolus. A third foramen is at the same level beneath P_3. In *Probathyopsis praecursor* Simpson the anterior mental foramen is below the canine.

The dental foramen is large and bounded above by a ridge extending forward and downward from the condyle entirely across the inner base of the ascending ramus.

The condyle is low, and faces both upward and backward; thus the lower jaw could swing downward through an arc of 90 degrees to hang perpendicular to the upper cheek tooth row. This condyle construction resembles that of later uintatheres, such as *Uintatherium* Leidy.

The angle of the lower jaw in both male and female is deflected strongly outward and downward, and arises abruptly from the horizontal ramus. The posteroventral margin is rugose and strongly ridged on the outside, especially in the male. The inner face of the angle in the male has two strong, anterodorsally directed ridges arising from that margin; there is a single such ridge in the female. The angle most strongly resembles that in *U. segne* Marsh. The angle in *Bathyopsoides harrisorum* Patterson is less clearly set off from the horizontal ramus. The form of the angle, coupled with that of

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EXPLANATION OF PLATE 76

All figures approximately $\times\frac{1}{2}$

FIGS. *1–19—Prouintatherium hobackensis*, n. gen. and n. sp. University of Michigan Museum of Paleontology catalogue numbers. Figures 1–15,18, and 19 are of paratype 34122. Figures 16 and 17 are of specimens numbered 34123. *1,2*, ulna, left, anterior and externolateral views, respectively. *3,4*, radius, left, anterior and externolateral views, respectively. *5*, femur, right, lateral view. *6–13*, eight different phalanges; *6,8,11*, distals; *9,12*, medials; *7,10,13*, proximals; lateral views in top row, ventral views in center row, dorsal views in bottom row. *14,15*, humerus, left, externolateral, and anterior views, respectively. *16,17*, midshaft cross-sections of humerus and radius, respectively. *18,19*, astragalus, left, possibly of *P. hobackensis*, dorsal and ventral views, respectively.

the condyle, suggests that the mouth could be opened widely, clearing the saber-like upper canines for action.

The masseteric fossa is normal, suggesting that the temporal muscle was of moderate strength. This correlates well with the premolar-molar series which is relatively weak compared with the size of the animal.

The symphysis of the male lower jaw (the condition is not known for the female) is long and deep. The ventral union is V-shaped. Viewed from above, the horizontal rami diverge broadly outward from the midline of the mandible, thus the skull may have had a relatively broad occiput. In contrast, the symphysis in *Probathyopsis praecursor* is shorter and shallower, and the incisors are set more transversely. In *Bathyopsoides*, the ventral union of the symphysis is U-shaped (Patterson, 1939, p. 374).

The flange of the lower jaw in the male holotype (UMMP 27249) is deep and arises abruptly from the horizontal ramus beneath P_4. It served to protect the enlarged upper canines. The jaws of the female paratype (UMMP 27250) are broken off at the posterior edge of the flange, but the shorter upper canines in the collection indicate that, as in some Bridger uintatheres (Marsh, 1886, p. 35, 37), the flange of the female was proportionately smaller. The flange, at least in the male, is much larger than in *P. praecursor* or *P. newbilli* Patterson. It is not preserved in the type of *P. successor* and, because of the small canines, that type might be a female, but direct comparison is not possible. In *Bathyopsoides* and *Bathyopsis*, the flanges, although as large as that of *Prouintatherium hobackensis*, arise more gradually from beneath M_1 and M_3, respectively.

The lower dentition is alike in the sexes except for the larger size and for the greater enlargement of the upper canines in the male. The incisors are broad, spatulate, and singly or doubly ridged on the lingual side. The basal cingulum is weak but complete. There is a well developed external heel. The size range of the isolated incisors is wide. The difference in size between I_1 and I_3 in one individual may have been great, as it was in other uintatheres, but no incisors were found in association. The incisors on the two sides of the mandible met at nearly a right angle at the symphysis and were aligned at about 45 degrees to the cheek tooth rows. They are much like the incisors of *P. successor* except that their heels are larger, as in *Uintatherium*, and some have two medial ridges on the lingual face. Their heels are much stronger and their lingual faces more crenulated than in *Bathyopsoides*.

The lower canines are smaller than the uppers, but distinctly larger than the incisors. They are long-rooted and have sharp edged, curving anterior and posterior margins.

P_1 was evidently absent as in some forms of *Uintatherium* (*Dinoceras* and *Tinoceras* of Marsh).

The talonid crests of the molars are not compressed; the hypoconulid is well removed from the metaconid, comparing closely in those respects with *Probathyopsis successor*, *P. newbilli* and *Bathyopsis fissidens*, and contrasting with the shorter crest in *Bathyopsoides* and the longer crest in *P. praecursor*.

The metastylids are less prominent than those of any of the genera mentioned in the paragraph above.

The entoconid is a distinct cusp, as in *Probathyopsis* and *Bathyopsis*, not subordinated to the hypoconulid as in *Bathyopsoides*.

The trigonids are less elevated than in *Bathyopsis*.

M_3 very closely resembles that tooth in *P. praecursor*, and when little worn has the hypoconulid united to the hypoconid-metastylid crest by a weak, forwardly directed ridge not found in *B. fissidens*.

P_4 is slightly larger than M_1 but M_1 clearly continues the premolar series in size, being much smaller than M_2 or M_3. Here *Prouintatherium* is like both *Bathyopsoides* and *Uintatherium*, whereas M_1 is intermediate in size between P_4 and M_1 in *Probathyopsis praecursor* and distinctly smaller than either of those teeth in *P. newbilli;* the condition in *P. successor* is not yet known.

The lower diastema is well developed being 31.3% as long as the premolar-molar series. There is little or no diastema in *P. newbilli*. The relative length of the diastema is not known for *P. successor*. The diastema/cheek tooth ratio in other forms is about

0.11 in *P. praecursor*, 0.33 in *Bathyopsoides* and *Bathyopsis*, and 0.44 in *Uintatherium segne* (taken from figure in Marsh, 1886). *Probathyopsis* is more primitive in this regard insofar as could be determined for the various species of that genus.

The skull of *Prouintatherium* is poorly represented, but by inference, from the shape of the mandible and its symphysis, may have been narrow in front and broad in the occipital region.

The great length of the upper canine root suggests that there were corresponding bony maxillary horns on the skull.

The infraorbital foramen lies above P^{2-3} on a line passing between those teeth. The anteroventral margin of the orbitotemporal fossa is opposite the center of M^3 and thus extends a shorter distance forward than in *Uintatherium*.

A tooth bearing maxillary fragment shows a distinct maxillary shelf extending laterally above the cheek teeth as in the middle Eocene uintatheres and as in *Bathyopsoides*. This portion of the skull is not yet described for *Probathyopsis* or *Bathyopsis*.

The upper incisors probably were absent as in other members of the order.

In the male (UMMP 27249) the upper canines are long, stout, acutely pointed, slightly recurved, triangular in outline, with sharp anterior and posterior edges and long, slightly curved roots. They are most like those described by Marsh (1886, p. 45) for *Uintatherium* [*Dinoceras*] *lucare*. They are more acutely pointed and less laterally compressed than those of *Bathyopsoides*. The upper canines of the female are much smaller, not triangular in cross-section, and closely resemble those of *Probathyopsis successor* (the type of which may be a female, although this cannot yet be proven).

Patterson (1939, p. 382) noted "the essentially static cheek teeth of the known uintatheres. . . . " *Prouintatherium* is no exception in this respect, differing from other uintatheres only in minor details. The upper molars are much like those of *Probathyopsis praecursor* except that in *Prouintatherium* the lingual margins are less rounded, the para- and metacones more widely separated, and the hypocones larger and more distinct.

A metacone is indicated on the upper premolars but does not rise free of the ectoloph whereas that cusp is distinct in *Bathyopsoides*. The protocone is a distinct cusp, but is lower than the metacone. P^2 is set with its ectoloph less than 45 degrees and more nearly parallel to the cheek tooth row than in *P. successor*. An anterior ridge unites the protocone to the ectoloph but it is less pronounced than in *P. successor*. A very weak posterior ridge from protocone to ectoloph completes the enclosure of a shallow basin. This has been noted by Jepsen (1930, p. 129) to be the condition in RP^2 but not LP^2 of *Prodinoceras* Matthew, Granger, and Simpson and is apparently a variable character of slight significance. P^2 in *P. praecursor* lacks this posterior ridge but is otherwise similar. P^4 in *Prouintatherium* is more angular, with the protocone more internal, and the basin more acutely triangular than in that species.

The upper molars lack parastyles as do those of *P. successor* and *P. praecursor;* however, the cingula of *Prouintatherium* are incomplete lingually, failing to encircle the bases of the protocones. The molar cingula of *Bathyopsoides* are said to be incomplete. The posterior molar lophs are shorter than in *Bathyopsis fissidens*. A ridge descends from the middle of the metaloph into a basin within the posterior cingulum on M^{1-3}. This ridge occurs on the upper molars of *P. successor* but only on M^3 of *P. praecursor*.

M^1 is slightly smaller than P^4 but distinctly smaller than M^2, thus appearing to be part of the premolar series. This is the common condition in both the early and late uintatheres except for *P. praecursor* in which M^1 is larger than P^4 and closer in size to M^2. However, M^1 in the type figure of that species is restored from a topotype and possibly is from an individual larger than the type.

M^{1-3} are much like those of *P. successor* in size, shape, and cusp pattern except that the protoloph of M^3 in *Prouintatherium* is less convex anteriorly and the lingual bases of the molars are less rounded.

Portions of an atlas and two other vertebrae (UMMP 27523) alone represent the vertebral column. The atlas is smaller and lighter but otherwise constructed like that of *Uintatherium*, especially *U.* [*Tinoceras*] *grande* Marsh (1886, figs. 84–86). The other two vertebrae, both incomplete, are of an-

TABLE 1—MEASUREMENTS OF *Prouintatherium hobackensis* (IN MILLIMETERS)

Characters	Holotype UMMP 27249 Male	Paratype UMMP 27250 Female	UMMP 27251 Female	UMMP 27252 Female? slightly distorted	Paratype UMMP 27523 sex?	Paratype UMMP 27254 sex?	Paratype UMMP 34122 sex?
Incisors, lower (ranges)							
Crown ht., lingual, unworn						15.2–20.1	
Ext-Int. at cingulum						11.0–14.4	
A–P at cingulum						8.5–10.2	
Upper canine		(min.)					
Root length below enamel	107.0	60.0					
Crown ht. (max.)	107.0	ca. 40.0	39.6				
A–P at enamel base	23.5	15.1	15.3				
Tr. at enamel base	18.2	11.6	11.1				
Lower canine							
Root length	56.6						
Crown ht.	33.5						
A–P at enamel base	15.4	12.6*					
Tr. at enamel base	12.2	8.2*					
P_2 to M_3, incl.	87.0						
P_2, at cingulum A–P†		11.7*					
P_2, at cingulum Tr†		6.8*					
P_3, at cingulum A–P	12.5		13.6*				
P_3, at cingulum Tr	8.3		8.5*				
P_4, at cingulum A–P	12.5	11.7*					
P_4, at cingulum Tr	9.5	9.2*					
M_1, at cingulum A–P	11.4						
M_1, at cingulum Tr	8.5						
M_2, at cingulum A–P	16.0	15.7*	15.8*				
M_2, at cingulum Tr	12.0	10.6*	10.9*				
M_3, at cingulum A–P	20.6	18.4*	20.4*				
M_3, at cingulum Tr	13.8	12.0*	13.0*				
P^2 to M^3		73.8					
P^2 A–P	11.6*	10.6	10.1*				
P^2 Tr	10.5*	9.6	9.8*				
P^3 A–P	11.8*	10.6					
P^3 Tr	13.6*	12.3					
P^4 A–P		10.5					
P^4 Tr		13.0					
M^1 A–P	11.0*	10.0	10.2				
M^1 Tr	12.2*	10.6	11.0				
M^2 A–P	16.3*	15.5	15.7				
M^2 Tr	19.4*	15.2	15.0				
M^3 A–P	18.5*	17.5	17.6	17.0* ca.			
M^3 Tr	20.2*	17.8	17.0	19.5* ca.			
Lower jaw							
Anterior edge of symphysis to posterior edge of condyle	232.0						
Post. edge canine alveolus to post. edge M_3	136.0						
Diastema, post. edge canine alv.-ant. edge P_2 alv.	39.0						
Max depth flange below alveol. of P_2	70.0						
Ext. depth hor. ramus below alveolus of M_3	42.0	33.3					

* Teeth of the premolar-molar series measured out of tooth row.

† Max. A–P and Tr. diameters of cheek teeth measured at cingulum parallel with or perpendicular to the long axis of the cheek tooth row.

TABLE 1—(*continued*)

Characters	Holotype UMMP 27249 Male	Paratype UMMP 27250 Female	UMMP 27251 Female	UMMP 27252 Female? slightly distorted	Paratype UMMP 27523 sex?	Paratype UMMP 27254 sex?	Paratype UMMP 34122 sex?
Vert. dist., upper surf. condyle to lower edge angle	72.0	67.0					
Humerus (incomplete. lacks ca. ¼ of prox. end) min. L.							187 min.
Humerus (incomplete. lacks ca. ¼ of prox. end) Tr., distal							72.0
Radius (lacking distal epiphysis) L							156.0 min.
Radius (lacking distal epiphysis) A–P, prox. end							25.7
Radius (lacking distal epiphysis) Tr., prox. end							39.5
Ulna L							224.0
Ulna A–P at mid. shaft							29.3
Ulna Tr. at mid. shaft							16.8
Femur (lacks head and trochanter)							221.0 min.
Atlas, depth					42.8		
Ant. thor. vert. neural spine length above post. zygap.					72.0		

terior thoracic type. Their neural spines are relatively longer and more slender than any described for *Uintatherium*.

The glenoid fossa of the scapula (UMMP 34122) is elongate and concave in the dorsoventral direction. The coracoid process is stout, blunt, and firmly welded to the scapular neck.

A nearly complete humerus (UMMP 34122) lacking the proximal end is short, straight, triangular in cross-section and constricted at the shaft midpoint, and strongly ridged. It closely resembles that bone in *Uintatherium* except that the ridges for muscle attachment are not heavily tuberculated. The deltoid ridge is large, with a broad and roughened upper portion. Both the olecranal and coronoid fossae are deep and nearly circular in outline. The posterior ridge for attachment of the latissimus dorsi is strong, roughened and slightly tuberculated. The shoulder musculature evidently was heavy by normal mammalian standards although not as heavy as that of *Uintatherium*.

The proximal end of the radius is transversely expanded and closely resembles that of *Uintatherium*. The radius articulates proximally directly in front of the ulna. A very rugose posteroexternal ridge opposes a similarly rugged and flattened surface on the anterior edge of the ulna.

The ulna is slightly heavier than the radius. The olecranon process is straight, not posteriorly deflected, thus forming a continuation of the long axis of the ulna. The greater sigmoid notch is deep, with an overhanging beak. The lesser sigmoid cavity is broad and faces almost directly forward for reception of the transversely expanded proximal end of the radius.

Cross-sections through the central portions of the shafts of the humerus and radius show that medullary cavities with perceptible boundaries are still present in the limb bones but that invasion of the cavities by cancellous bone had begun. The invasion is complete and the cavity boundaries obliterated in larger and more heavily built *Uintatherium*.

Thus the radius and ulna of *Prouintatherium* are much like those of the advanced, middle Eocene uintatheres. Marsh (1886, p. 93, 96) suggested that the arrangement in *Uintatherium* indicated strong ligamentary attachment of the radius and ulna with resultant loss of rotational mobility in the lower forelimb. The straight olecranon process and positions of articular surfaces on the humerus, radius and ulna, indicate that in the standing-rest position the elbow angulation of *Prouintatherium* was about 90

degrees. Mounted skeletons of mid-Eocene uintatheres figured by Marsh (1886) show a surprising degree of elbow angulation. Their forelimbs had not achieved the graviportal form one would expect to find in such heavy bodied animals. Nevertheless, the even greater angulation in *Prouintatherium* suggests a relatively lighter body form.

The sole femur in the collection (UMMP 34122) is incomplete but the total length probably did not exceed 300 mm., so it seems to have been shorter than the femur of *Bathyopsoides harrisorum* (428 mm., Patterson, 1939, p. 378). The specimen is crushed nearly flat anteroposteriorly. The bone may have been compressed in its normal form and less resistant to stress in that direction, much like the femur in some Bridger uintatheres.

Four astragali are in the collection. Three of these are large and no doubt belong to *Coryphodon*. The fourth is smaller than the other three but seems too large to belong to *Prouintatherium*. However, if it does belong to that genus it is relatively short anteroposteriorly and broad transversely compared to the astragali of the Bridger forms.

The phalanges are short and broad. Their proximal articular surfaces bear a shallow central groove, whereas the phalanges of later uintatheres are said to lack such a groove. However, the ungual phalange is especially short and broad and very rugose, much like those described and figured for *Uintatherium*.

SUMMARY AND CONCLUSIONS

Insofar as comparable parts are available for comparison, *Prouintatherium hobackensis* is most like *Probathyopsis successor*, although the two are not identical. Unfortunately, the comparable parts are the cheek teeth, structures that seem to have remained almost static throughout uintathere history while other structures, such as flange construction, size, and body proportions, changed radically. One may infer that minor differences in dentition might have been associated with greater differences of taxonomic significance in other skeletal parts.

In upper canine construction (and by inference in flange construction) the male of *Prouintatherium hobackensis* is clearly unlike the holotype of *Probathyopsis successor*, which had a small upper canine, yet the female of *Prouintatherium* is similar to *P. successor* in that respect. There are, however, certain differences between the two species in tooth construction that are as great as those between *P. successor* and other known members of the genus *Probathyopsis*. *P. hobackensis*, although smaller, also closely resembles or at least has progressed toward the middle Eocene uintatheres, like *Uintatherium* and *Elachoceras*. This is especially true of its upper canine and associated lower jaw flange, length of diastema, form and position of the condyle and angle of the lower jaw, and the forms and relations of the bones of the forelimb. The problem of classifying the Hoback specimens is made difficult mostly by the incompleteness of the type of *Probathyopsis successor*. I considered several taxonomic possibilities and procedures as follow:

1. That the smaller jaws and upper canines in the Hoback collection belong to *Probathyopsis successor* and the larger ones to a new species or even a new genus. This seemed improbable because of the provenance of the specimens and because of their exceedingly close resemblance in all respects but size and canine form.

2. That the specimens represented both sexes of one population. This seemed highly probable and was accepted as a basis for taxonomic description.

3. That the Hoback specimens of both sexes belonged to *P. successor* and that the type of that species is a female, the male being as yet unknown. This cannot yet be supported by specimens. Moreover, as far as comparable parts are known, *P. successor* just as closely resembles *P. praecursor* and *P. newbilli*, two species which it seems had barely begun canine and flange enlargement. A high degree of coincidence is required to postulate that all known specimens of those species represent females. I rejected this proposition, not because it is impossible, but because it is now both improbable and unsupportable.

4. That the Hoback specimens and the type of *P. successor* are conspecific and that all should be placed in a new genus on the basis of the structural advances the Hoback specimens show over *P. praecursor* and *P. newbilli*, but with *P. successor* as the genotype. This proposition is clearly possible,

but its acceptance would require (a) minimizing the minor but perhaps significant differences between the essentially static cheek teeth of *P. successor* and the Hoback specimens, (b) inferring that the type of *P. successor* is a female, and (c) ignoring the equally close resemblance between *P. successor* and the other two species of *Probathyopsis* both of which lack enlarged upper canines and enlarged jaw flanges. I avoided this taxonomic course, although it is in theory quite possible, because it is in fact unsupportable and because of the incompleteness of the type and only known material of *P. successor*.

5. That the Hoback specimens represent a new genus and species of early Eocene uintatheres, clearly more advanced toward the middle Eocene forms than either *P. praecursor* or *P. newbilli* and quite possibly advanced beyond *P. successor*. This was accepted, together with proposition (2) above, as the final basis for classification.

I conclude, then, that *Prouintatherium hobackensis* represents a new genus of early Eocene uintatheres of relatively small size compared with the middle Eocene forms, but clearly showing change directly toward *Uintatherium* and *Elachoceras* and away from *Probathyopsis* in many aspects of its jaw and limb structure.

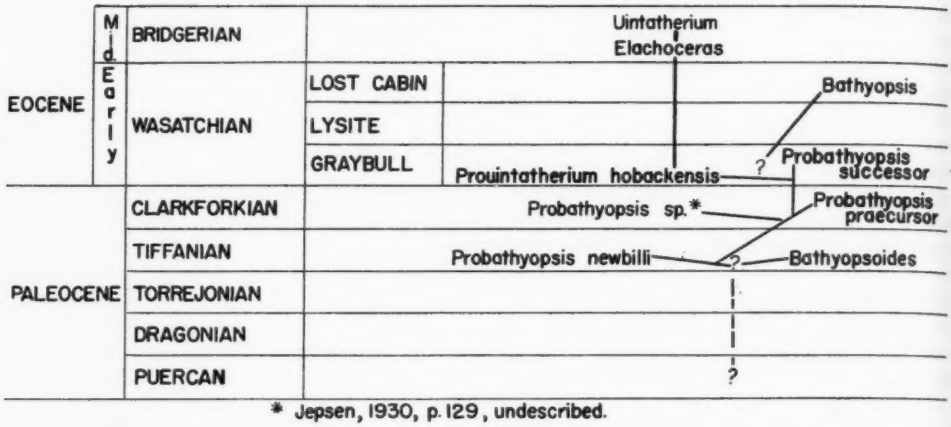
Patterson (1939, p. 382), after describing *Bathyopsoides*, stated,

> The structural succession *Probathyopsis-Bathyopsis-Elachoceras-Uintatherium-Eobasileus* admirably illustrates the trend of evolution in the later uintatheres. This succession has been regarded as phyletic, but *Bathyopsoides* suggests that such a view may not be entirely correct. *Probathyopsis* may well have been ancestral to *Bathyopsis* but I am by no means certain that the latter is in turn ancestral to the later members of the order. In at least one striking character—flange structure—*Bathyopsoides* is closer to *Uintatherium* than is *Bathyopsis*. Although we have no evidence at present that the Dinocerata had as complex a radiation as the Pantodonta, it is nevertheless likely that future discoveries will reveal that the genera we know now [1939] are inadequate in number for a proper understanding of the phylogeny.

The new genus, *Prouintatherium*, now provides some important information on uintathere phylogeny. This genus probably is slightly more recent (earliest Eocene) than *Bathyopsoides* (late Paleocene) yet so nicely combines certain characters of the ancestral group, *Probathyopsis*, with those of later uintatheres as to suggest that it is more nearly intermediate than *Bathyopsoides* in both a structural and temporal sense. This is especially true of the flange structure of the lower jaw, a character upon which Patterson (see quotation above) has placed much emphasis. The intermediate position of *Prouintatherium* is reflected in the following summary:

Primitive characters	Intermediate characters	Advanced characters
1. Relatively primitive cheek teeth (but conservative in all genera)	1. Bones of the forelimb heavily ridged but not tuberculated	1. Enlarged upper canines
2. Small size	2. Medullary cavities of limb bones partially invaded by cancellous bone	2. Deep and abrupt lower jaw flange
3. Acute forelimb angulation		3. Strong, abrupt, deflected jaw angle
4. Long, slender neural spines		4. Condyle of jaw low, facing up and back
		5. Diastema long
		6. Forelimb shape and proportions
		7. Skull narrow in front, broad at occiput, probably with maxillary horns

Although *Bathyopsoides* certainly possessed enlarged upper canines, they do not resemble those of the middle Eocene uintatheres as closely as do those of *Prouintatherium*. It seems possible that large size, enlarged flanges, and long canines were inherent potentials in uintatheres in general so that those characters in *Prouintatherium*, *Bathyopsoides* and *Bathyopsis* may have arisen more or less independently but in nearly parallel fashion. If this inference is valid it would support Patterson's suggestion (see quote above) that the Dinocerata may have had a more complex radiation than previously supposed. Text-figure illustrates a hypothetical phylogeny based upon this inference and upon the specimens described in this paper.



TEXT-FIG. *1*—Hypothetical phylogeny of Paleocene and early Eocene Dinocerata.

Gazin (1956, p. 16) suggested that *Bathyopsoides* might be a male *Probathyopsis*. This would tend to imply that the type specimen of *P. newbilli* (and perhaps *P. praecursor*) is a female. His suggestion was based, in part, upon my discovery report and preliminary study (Dorr, 1951, p. 89) of the Hoback specimens. Gazin's suggestion seems improbable for several reasons. As Gazin was aware, Patterson (1939) noted differences between those two genera in other features in addition to size and canine form, notably different cusp patterns on M_2. It is true that there are dental resemblances between the two genera, but the same is equally true for all Dinocerata. Finally, *Bathyopsoides* is clearly unlike *Prouintatherium* in jaw structure; yet *Prouintatherium*, which is distinct from *Probathyopsis* in many respects, still resembles the several species of *Probathyopsis* more closely than does *Bathyopsoides*.

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MANUSCRIPT RECEIVED JUNE 18, 1957.

EXPLANATION OF PLATE 77

All figures approximately $\times \frac{1}{2}$

FIGS. *1–24*—*Prouintatherium hobackensis*, n. gen. and n. sp. University of Michigan Museum of Paleontology catalogue numbers. *1–6*, paratype, 27254, lower incisors, possibly from more than one individual, showing range of size variation; sexes and individual sizes unknown. *1–3*, lingual views; *4–6*, lateral views. *7,8*, holotype, 27249, adult male; *7*, lingual view of left lower canine; *8*, anterior view of right lower canine. *9–13*, paratype, 27250, adult female; *9*, side view of right lower canine (lacking root and tip); *10,11*, occlusal views of RP_2 and RP_4, respectively; *12,13*, fragmentary upper canines arranged to supplement one another in missing parts. *14–20*, holotype, 27249, adult male; *14,15*, fragmentary upper canines arranged to supplement one another in missing parts; *16–20*, occlusal views of LM^2, LM^3, RP^2, RP^3, and RM^1, respectively. *21–23*, paratype, 27523, sex?, lateral view of anterior thoracic vertebra, and dorsal and posterior views of atlas, respectively. *24*, paratype, 34122, sex?; lateral view of fragmentary right scapula; subcircular, dark patch is an ironstone concretion.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 517–524, PL. 78, 3 TEXT-FIGS., MAY 1958

THE PALEOZOIC OSTRACODE GENUS *ALANELLA* BOUČEK, 1936[1]

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ABSTRACT—The genus *Alanella* is redefined, and a new species from the Devonian of New York, *A. devonica*, is described. Two species previously assigned to *Bairdia* are here assigned to this genus, of which one junior primary homonym is renamed.

INTRODUCTION

THE INTERNAL structures of well preserved specimens of a species of *Alanella* from the Middle Devonian of New York add considerable data as to the affinities of the genus. Agnew (1942, p. 756) questions the assignment of this genus to Ostracoda, but Henningsmoen (1953, p. 247) includes it in his suborder Paleocopa. The presence of a well developed inner lamella confirms the ostracodal affinities of the genus, and, coupled with the absence of a frill, removes it from the Paleocopa. We are grateful to Dr. Vladimír Pokorný, Prague, Czechoslovakia, for unpublished data on the differences between *Čelechovites* and *Alanella*. Jean M. Berdan, U. S. Geological Survey, assisted by numerous discussions, and made available for examination specimens of *Alanella* from the Lower Devonian of New York.

Alanella and the family Alanellidae were established by Bouček (Bouček, 1936, p. 71) for the type species, *A. bohemica*, and a subspecies or "mutant," *A. bohemica decurtata*. According to Bouček, the type species is based on about a dozen valves from gray slabby limestone of the transition between *e* beta and *e* gamma zones in the Ludlow Series (Upper Silurian) of Budňany, Bohemia. *A. bohemica decurtata* was based on eight valves from gray lenticular limestone in the lower part of the upper *e* beta zone. This zone was subsequently designated by Bouček & Přibyl (1955, p. 641) as the zone of *Pristiograptus ultimus* in the Middle Ludlow Series from Kolednik near Beroun, Bohemia. According to Bouček (1936, p. 36) the specimens are poorly preserved. The original illustrations are drawings with parts shown as reconstructed, suggesting that the specimens are embedded in matrix.

On several slabs of a gray platy limestone (USNM 115412) the bedding planes are crowded with *Alanella bohemica decurtata* Bouček, 1936, *Laccoprimitia subcentralis* Bouček, 1936, and *Aechmina cuspidata* Jones & Holl, 1869. This is topotype material of *Alanella bohemica decurtata*, and a similar slab is illustrated by Bouček (1936, pl. 6, fig. 2). The specimens are very poorly preserved shells; excavation with a needle disclosed that some are steinkerns. The preservation of the shell material is inadequate to determine internal structures; consequently, comparison has to be only on external features.

Bouček (1936, pl. 71) referred the generic description to his diagnosis of the new

[1] Publication authorized by the Director, U. S. Geological Survey.

EXPLANATION OF PLATE 78

All figures ×34

FIGS. *1–15*—*Alanella devonica* Kesling & Sohn, n. sp. *1–8*, right lateral, dorsal, left lateral, and ventral views of two carapaces, paratype UMMP 30522 and holotype (figs. 5–8) UMMP 30521. *9–17*, right lateral, dorsal, and left lateral views of three carapaces, paratypes UMMP 30523, 30524, and 30525. Middle Devonian, New York.

18,19—*Alanella decurtata* Bouček, 1936. Right and left views of two specimens, topotypes USNM 115412. Silurian, Middle Ludlow, *Pristiograptus ultimus* zone, Kolednik, Czechoslovakia.

family Alanellidae. His diagnosis follows: "Fusiform ostracodes with straight hinge margins that project on both ends into a spine; ventral margin with wing-like vela (Saume)." He refers to the "velum" (Saum) in the description of both the type species and the subspecies. Bouček & Přibyl (1955, p. 640) elevated the subspecies to specific rank, and illustrated three specimens from an additional, slightly stratigraphically older horizon. Again they refer to the species in the English summary as possessing a "velum."

The term "velum" (Saum) as used by Bouček is not the same structure as defined by Hessland (1949, p. 130) and Kesling (1951, p. 118). *Velum* as defined by Hessland is a "broad velate structure," and *velate structure* is defined by Kesling as "any elongate *elevated* [italics ours] structure parallel to the free edge of the valve . . . " A wide velate structure is called a *frill*. Henningsmoen (1953, p. 247) intrepreted "Saum" as a frill. The illustrations of *Alanella* and topotype specimens of *A. decurtata* demonstrate that the feature referred to as "Saum" is not a frill, but the ventrolateral pinching of the valves as illustrated in text-figs. 2c–g, r–w.

This ventrolateral pinching is present also in the Czechoslovakian genus *Čelechovites* Pokorný, 1950, based on a single damaged specimen of *Č. cultratus* Pokorný, 1950, from the Givetian (Middle Devonian) red marly coral limestone. Dr. Vladimír Pokorný very generously reexamined his type specimen at the National Museum in Prague, and writes that Bouček's types are not available at present. We quote his opinion regarding *Čelechovites* (letter to Sohn, Jan. 9, 1957):

> When comparing the figures of Bouček, 1936, and Bouček and Přibyl, 1955, I think, that *Alanella* and *Čelechovites* are not congeneric. The configuration of the anterior and posterior end of *Čelechovites* is decidedly different. This is not caused by the preservation. The anterior (rounded) end of *Čelechovites* is only very slightly corroded in its upper part; there is no sign that there were any terminal spines developed at the dorsal angles. Both ends of *Č.* are strongly asymmetrical.

Determination of the affinities of *Alanella* and *Čelechovites* must await future study of better preserved examples of both genera. We refrain from comment on the status of the family Alanellidae, except to note that Berdan considers this family as a junior synonym of Beecherellidae Ulrich, 1894 (1897) (Berdan *in* Moore, in preparation). In the meantime, we regard the North American species as a member of *Alanella*, and are reasonably certain that the internal structures observed in our species are very likely similar to those that exist in the European representatives of the genus.

INVESTIGATION OF INTERNAL STRUCTURES

To determine the nature of internal structures, each of three carapaces was studied as a series of polished surfaces at right angles to the hinge line. The procedure may be of interest to those workers who wish to learn about structures inside small specimens.

Outlines of each carapace in dorsal, lateral, and ventral views were drawn with the aid of a camera lucida. These outlines were used later to locate the exact position of each polished surface.

Each carapace was embedded in a block of clear bioplastic with the hinge line vertical (perpendicular to the surface of the block). The bioplastic was cured for several days according to the manufacturer's recommendations. Each block was ground on a glass plate with 1000-mesh carborundum powder to the desired level in the specimen, washed, and dried. A drop of cedar oil and cover glass were placed on the polished surface. The contact of the shell material and the steinkern was clearly discernible. Two camera lucida drawings of each surface were made, one as a check on the other. This process was repeated for about 25 successive levels for each specimen.

Inasmuch as the camera lucida drawings of the carapaces and of the polished surfaces were made at the same magnification, the position of each surface could be readily determined from the dimensions of the drawing.

Although the blocks were ground down by the same number of movements each time, it was found that the levels were not equally spaced throughout a specimen. When all drawings were finished, therefore, composite drawings were made for levels at selected intervals. Text-fig. 1 is a composite

drawing based on the three carapaces, with the selected intervals marked by vertical lines. Text-figs. 2a–x show successive cross-sections, each made as a composite of the actual polished surfaces of the three specimens at approximately the indicated position in the carapace.

Text-fig. 3 contains reconstructions of valves and carapace based on the cross sections. In text-figs. 2a–f, sections are drawn as seen at an angle of 45 degrees (from the front and from the rear) and reassembled in the relative positions they would occupy in the carapace. The nature of hinge and duplicature revealed in this way is of particular interest.

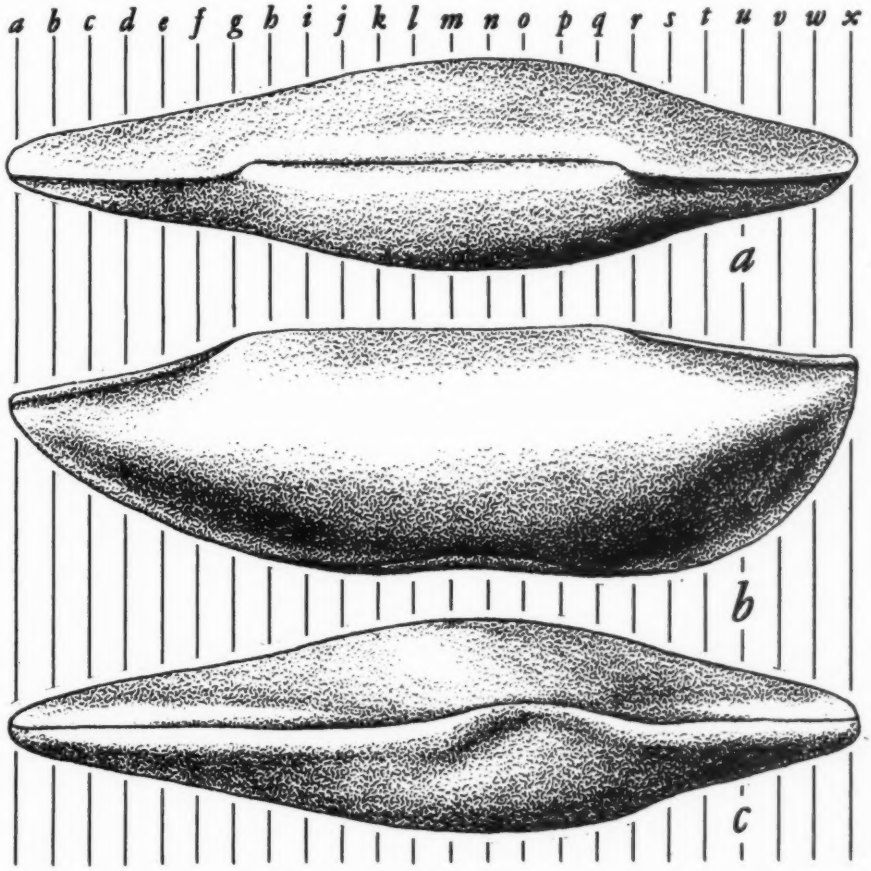
SYSTEMATIC DESCRIPTION

Genus ALANELLA Bouček, 1936

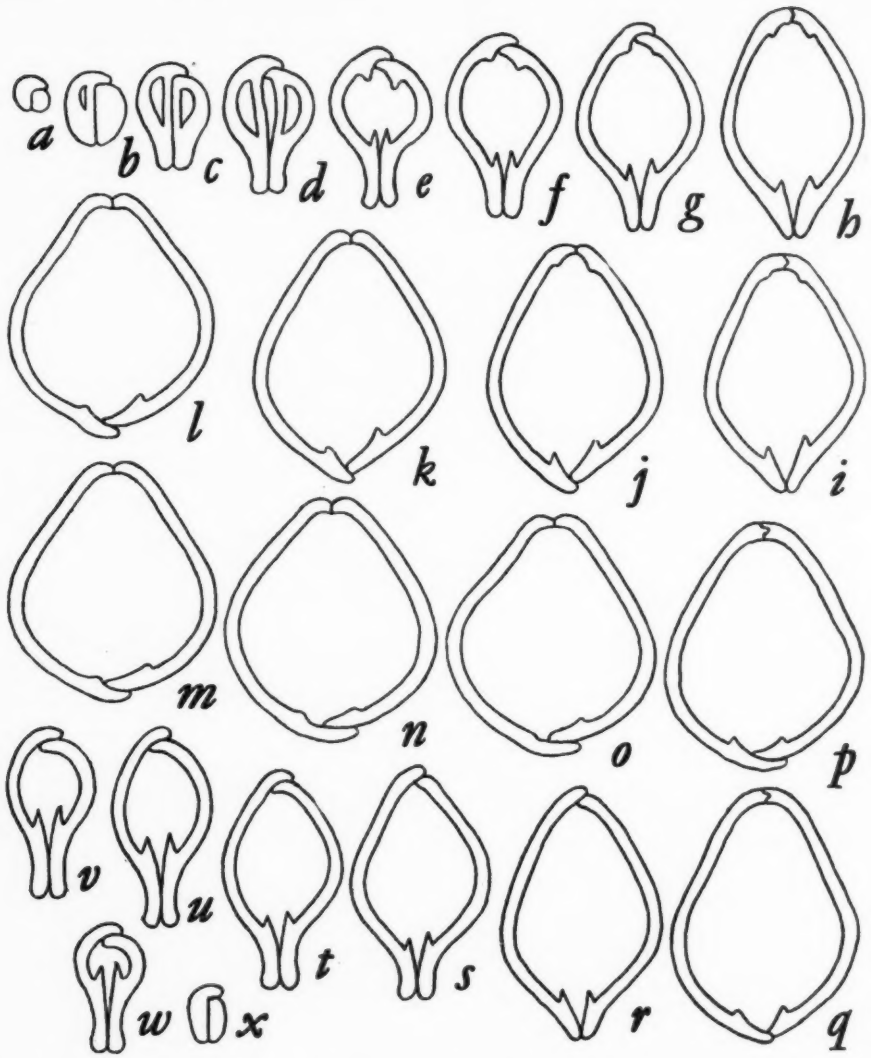
Alanella Bouček, 1936, p. 71. Henningsmoen, 1953, p. 247,265. Bouček & Přibyl, 1955, p. 587,615,639.

Type species.—By original designation, *A. bohemica* Bouček, 1936, p. 71, pl. 5, figs. 2a,b,3a,b. Upper Silurian, Czechoslovakia.

Diagnosis.—Smooth, elongate ostracodes, acuminate at each end, ventroterminal areas pinched. Hinge line straight or slightly convex, central portion without structure or overlap, terminal portions with ridge on left valve and corresponding groove on right valve. Left valve slightly larger, overlapping



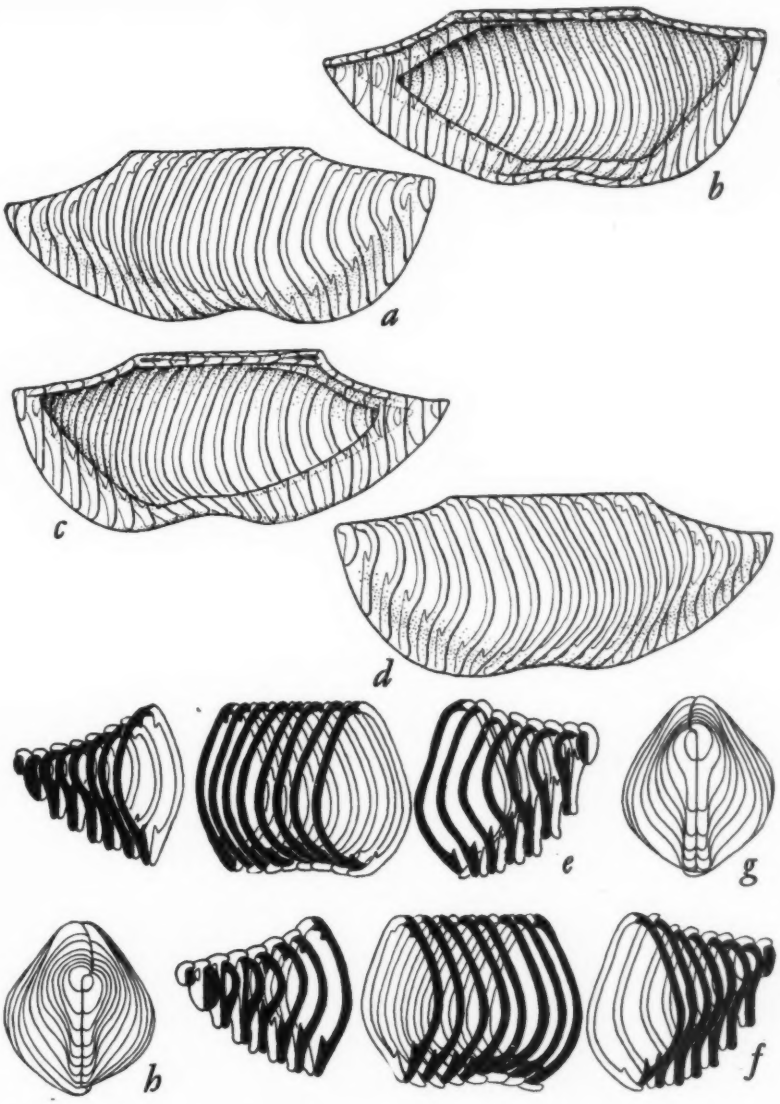
TEXT-FIG. 1—*Alanella devonica*, n. sp. *a–c*, dorsal, right lateral, and ventral views of a carapace drawn as a composite of three specimens later destroyed in making series of polished surfaces. The vertical lines mark the positions of cross sections shown in text-figs. 2 and 3; the small letters at the top correspond to sections in text-figs. 2a through x. ×50.



TEXT-FIG. 2—*Alanella devonica*, n. sp. *a–x*, posterior views of successive cross sections from posterior to anterior through a carapace, in the positions indicated in text-fig. 1. Each cross section is a composite based on polished surfaces of three specimens. In the posterior region of each valve, the space within the valve (sections *b–d*) is a vestibule between the outer lamella and the duplicature. The duplicature is also broad in the anteroventral region of each valve (sections *u–w*) but here it does not extend across the valve. The hinge extends from section *h* through section *q*. ×50.

on terminodorsal and on ventral borders, but not on terminoventral or on hinge borders. Duplicature well developed posteriorly, extending across the inside of the valve from dorsal to ventral margins for about $\frac{1}{9}$ of the greatest length of the valves, forming two long hemiconical vestibules; narrow along the ventral margin, and slightly wider along the anterior margin.

Discussion.—Kummerow (1939, p. 38) described *A. inermis* from the Viséan of Rheinland, Germany, and Bouček & Přibyl



TEXT-FIG. *3—Alanella devonica*, n. sp. *a–d*, valves reconstructed from the series of successive cross sections shown in text-fig. 2, each shown as seen from the front at an angle of 45 degrees; *a*, exterior view of right valve; *b*, interior view of left valve, showing the hinge, duplicature, and overlapping parts of the valve; *c*, interior view of right valve showing the hinge and duplicature; *d*, exterior view of left valve; *e,f*, posterior, middle, and anterior thirds of a carapace in anterolateral and posterolateral views, respectively. The right valve is shown in solid black segments and the left in outlined segments to emphasize the manner in which the two fit together. Hinge, overlap, and shape of the valves are effectively illustrated in these views; *g,h*, sections in natural relationship as seen from the front and from the rear. The shape of the anteroventral and posteroventral concave areas can be readily interpreted. ×37½.

(1955, p. 640) state that they have an undescribed Viséan species of *Alanella* from Bystrice nad Olsi, Czechoslovakia. Although *A. inermis* Kummerow, 1939, is inadequately illustrated and described, the illustrations (1939, pl. 4, figs. 4a,b) suggest that part of the shell is exfoliated on the centrolateral portion of the valve, and is missing along the ventral and end margins. This species is here questionably referred to *Alanella*.

Two species, one from Europe and the other from North America, which were previously referred to *Bairdia*, are here tentatively assigned to *Alanella*.

The stratigraphic range of *Alanella* is Upper Silurian to Devonian, Mississippian (?).

ALANELLA BOHEMICA Bouček, 1936

Alanella bohemica Bouček, 1936, p. 71, pl. 5, figs. 2a,b,3a,b. Upper Silurian, Czechoslovakia.

ALANELLA DECURTATA Bouček, 1936
Pl. 78, figs. 18,19

Alanella bohemica var. *decurtata* Bouček, 1936, p. 71, pl. 5, figs. 1a,b, pl. 6, fig. 2. Upper Silurian. Czechoslovakia.

not *A. decurtata* Bouček. Bouček & Přibyl, 1955 [=*Alanella* sp. A].

ALANELLA? DUBIA Kesling & Sohn, new name

Bairdia rostrata Péneau, 1929, p. 178, pl. 9, fig. 8, pl. 11, figs. 6a,b (not Issler, 1908). Upper Famennian, *Glymenia* beds. Saint-Julien-de-Vouvantes, Ardmoricain Massif, France.

Péneau's name is a primary junior homonym that is here renamed. The original of pl. 9, fig. 8 is probably a steinkern; the illustrations on pl. 11 suggest that this species may belong to *Alanella*.

ALANELLA? INERMIS Kummerow, 1939

Alanella inermis Kummerow, 1939, p. 38, pl. 4, figs. 4a,b. Middle Viséan S. Binnsfeldhammer bei Stolberg, Rheinland, Germany.

See discussion under the genus.

ALANELLA LENTICULATA (Stewart & Hendrix), 1945

Bairdia lenticulata Stewart & Hendrix, 1945, p. 110, pl. 12, fig. 11. Olentangy shale, Delaware County, Ohio.

The holotype and only specimen is a steinkern with remnants of shell material along the dorsal margin that were described as the dorsal overlap.

ALANELLA sp. A

Alanella decurtata Bouček. Bouček & Přibyl, 1955, p. 588,615,640, pl. 2, figs. 18,19, pl. 3, fig. 11. Kopanina Limestone, *e* beta$_1$, near Kosov, Czechoslovakia.

Although Bouček & Přibyl state that the dorsal margin is more curved than illustrated on the holotype, paratypes of *A. decurtata* (pl. 78, figs. 18,19) do not have the very convex dorsal margin of the specimens illustrated in 1955, nor are the dorsoterminal margins as concave as in this species.

ALANELLA DEVONICA Kesling & Sohn, n. sp.
Pl. 78, figs. 1–17, text-figs. 1–3

Diagnosis.—A species of *Alanella* with ends that are not terminated by large spines, straight dorsal margin, and concave ventral margin.

External features.—Carapace in lateral view elongate, acuminate at each end; in dorsal view spindle-shaped; in end view oval. Left valve slightly larger than right, overlapping it on anterodorsal and posterodorsal (terminodorsal) borders and on ventral border, but not on dorsal or on anteroventral and posteroventral (terminoventral) borders. Greatest height of each valve anterior, midway between the center and the anterior end. Greatest width slightly anterior to midlength. Length approximately 3½ times the height and 4 times the width of the carapace.

Hinge line straight, slightly less than half as long as entire carapace, a little depressed below the dorsal border. Anterodorsal border nearly straight, slightly concave, meeting anteroventral border at an angle of about 70 degrees. Anteroventral border evenly curved with radius of curvature about equal to the height of the valve. Ventral border distinctly concave at or slightly in front of midlength, curving smoothly into anteroventral and posteroventral borders. Posteroventral border gently curved, meeting posterodorsal at an angle of about 60 degrees. Posterodorsal border nearly straight, slightly concave. Anterior half of each valve more plenate than posterior.

As seen in dorsal view, edges of overlap-

ping anterodorsal and posterodorsal parts of left valve distinctly offset from the hinge line. As seen in ventral view, overlapping part of the left valve liplike, curving evenly at front and rear into the rest of the free edge.

Lateral surface smooth. Narrow margins along anteroventral and posteroventral borders developed as low gently convex ridges, each bordered dorsally by a sublanceolate concave area. Concave area in posteroventral region narrower, longer, and deeper than that in anteroventral region.

Internal features.—Certain internal structure have been revealed by the method discussed above.

Hinge long and straight. End regions of hinge (text-figs. 2h,i, p,q) consisting of elongate grooves in right valve (text-figs. 3a,c) and corresponding ridges in left valve (text-figs. 3b,d). Central part of hinge (text-figs. 2j–o) without interlocking structures or overlap.

Duplicature remarkably well developed posteriorly (text-figs, 2,3b,c), extending across the valve (text-figs. 2b–d) and anteroventrally broader than one-third the greatest height of the valve (text-figs. 2u–w). Line of concrescence clearly defined in each valve (text-figs. 3b,c). On polished surfaces, a faint line extending from the line of concresence to the ventral edge of the valve is assumed to be the adhesive strip; the ventral part of each valve, therefore, is about equally divided into outer lamella and duplicature. In the posterior region, the duplicature extends completely across the valve (text-figs. 2b–d), enclosing a rather long, hemiconical vestibule (text-figs. 3b,c). Vestibule rather shallow along ventral part of each valve (text-figs. 2i–q); along the anterior part, developed as a curved V-shaped trough (text-figs. 2s–w, 3b,c). Duplicature apparently continuing dorsad from the posterior region as a low ridge under the rear part of the hinge (text-figs. 2e–h). In a closed carapace, duplicatures of the two valves nearly parallel and in contact in the anteroventral and posteroventral regions (text-figs. 3e,f), diverging proximally at an angle of about 10 degrees.

Types.—Type specimens are deposited in the Museum of Paleontology of the University of Michigan (UMMP) and in the United States National Museum (USNM). The following measurements are given in millimeters; parentheses indicate the specimen is incomplete.

	Greatest length	Height	Width
Holotype UMMP 30521	2.18	0.62	0.54
Paratype UMMP 30522	(1.97)	.65	.50
Paratype UMMP 30523	1.91	.58	.52
Paratype UMMP 30524	(1.85)	.55	.51
Paratype UMMP 30525	(1.74)	.54	.52
Paratype USNM 134722	1.74	.49	
Paratype USNM 134723	(1.72)	.56	
Paratype USNM 134724	2.03	.64	
Paratype USNM 134725	1.94	.54	
Paratype USNM 134726	1.00	.38	

Type locality.—Cut of the Delaware, Lackawanna, and Western Railway, 1½ miles west of East Bethany, Genesee County, New York. Collected by the late Raymond R. Hibbard and Robert V. Kesling in 1953.

Type level.—Centerfield limestone member of the Ludlowville shale (Hamilton group) of Middle Devonian age in western New York.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 525–540, PL. 79, 5 TEXT-FIGS., MAY 1958

PERMIAN CONCHOSTRACAN-BEARING BEDS OF KANSAS

PART 1. JESTER CREEK SECTION—FAUNA AND PALEOECOLOGY

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ABSTRACT—A detailed section containing fresh-water conchostracan-bearing argillaceous limestone of Middle Wellington age (Jester Creek, Harvey County, Kansas) is described and the fauna illustrated. One new species *Isaura* (*Euestheria*) *harveyi*, Forms A and B, and three new subspecies, *harveyi harveyi*, *harveyi wellingtoni*, *harveyi leonardii*, are described and figured. Statistical data on the parent species and most abundant subspecies are graphically shown and analyzed. Jones' specimens of *Estheria minuta* from Sumner County, Kansas, described in 1898, are shown to belong to Form B of the new species.

The paleoecology is reconstructed based on a consideration of the following: conditions of sedimentation, faunal associates of the conchostracans, insoluble residues, arthropod molts, and the conchostracan fauna. Data on the succession of conchostracan generations are applied to the problem of a plausible annual rate of sedimentation, and the figure of 0.04 inch per year is derived. Applying this figure to the conchostracan-bearing horizons results in an estimate of 100 ± 50 years as the total time that this particular pond was inhabited by clam shrimps during Permian time.

The valve character "flare" is thought to be sex-linked and to characterize females in the new species. The variability of this character is discussed and illustrated as it affects subspeciation.

INTRODUCTION

SPARSE information is available on the paleontology of the fresh water Leonardian conchostracan-bearing beds of Kansas and Oklahoma (Norton, 1939, Raymond, 1946, Swineford, 1955). At best, certain horizons are designated as containing estheriids. Often, conchostracans (clam shrimps) are incorrectly referred to as "brine shrimps" (=*Artemia*). While Swineford recently filled a gap in our understanding of the petrology of the Upper Permian, the sedimentology, paleoecology, paleontology, and stratigraphy of the conchostracan beds in particular have not received similar attention.

Because of this cursory consideration of the conchostracan beds, a series of misconceptions has grown up. In addition to the one noted above, others include:

(1) *Species.* It has been thought until now that all the individuals found in the dense conchostracan populations can be lumped in one undifferentiated species of either *Estheria* (a preoccupied name) or *Cyzicus*. [The validity of the inadequately described genus *Cyzicus* which was based on living forms has been disputed by the present writer. A brief has been filed with the International Commission in favor of the name *Isaura* Joly. However, biologists strongly favor retention of *Cyzicus* even though it is virtually a meaningless name. In this paper, *Isaura* Joly will be used pending the Commission's decision. The genus *Isaura* (=*Cyzicus*=*Estheria*) was subdivided into two subgenera to accommodate fossil material. (Tasch, 1956, Table 1; Tasch, ms.).]

(2) *Ontogeny, morphology,* etc. Not only have all the Kansan conchostracans been viewed as one species, but there appears to have been no appreciation of the fact that on any given plane, the valves represented right and left, juvenile and adult, (small valves have been called "dwarf"), and that the great variability in adult valves might be an expression of sexual dimorphism.

(3) *Faunal associates.* It has been generally accepted that no micro-faunal or floral associates are to be found in the Kansan conchostracan beds. Nor have any been previously reported.

(4) *Lithology.* In the Jester Creek section described in this paper, the distinctive conchostracan-bearing beds were not previously designated as limestone-argillaceous limestone. Yet, the insoluble residue is less than fifty per cent, and in outcrop, it forms a unit distinct from the upper and lower shales.

In addition, no statistical data for any

American Permian conchostracan species have been published to date. The estheriids are still known only in terms of individual specimens and not as populations. The concept of the succession of generations as discussed in this paper is based on a stratigraphical-biological approach to conchostracan-bearing horizons. It opens up a fruitful area for further investigation.

The investigation described in this paper is a pilot study, the forerunner of an ongoing extensive program of field and laboratory study of the Leonardian fresh water basins of Kansas and Oklahoma. The data and discussion that follow will, it is hoped, provide in part some clarification of the misconceptions noted above and contribute some information on Permian fossil conchostracan populations.

ACKNOWLEDGEMENTS

Field and laboratory work were financed by an award from the University of Wichita Research Fund. The following geology majors at the University of Wichita aided in the preparation of this report: Emory Shepard, Jerry Stude, Don Dalrimple. Bernard Shaffer acted as field assistant and prepared the illustrations. Continued field and laboratory work has been made possible by a two year grant from the National Science Foundation. It is a pleasure to acknowledge this assistance.

JESTER CREEK SECTION

The general position of this section has been reported to be Middle Wellington. However, there appear to be no precise data on its correct stratigraphic placement relative to the Carlton dolomitic limestone member. A program designed to obtain such information is now underway. The present study has been solely concerned with collection and analysis of the field and laboratory data about this section.

The entire exposure has slumped towards the creek. Channeling up to the soil and down to the creek floor was necessary to expose undisturbed beds. The conchostracan horizons continue in outcrop for some thirty feet curving with the bend of the Creek's North Branch. Exploration of the Creek's several branches has already begun. It is anticipated that due to slump and a thick soil cover, extensive channeling and hand coring in open fields will be necessary.

JESTER CREEK SECTION

(Harvey County, Kansas. N. line NW¼ NW¼ sec. 15, T. 24 S., R. 1 E, East bank of Jester Creek.) (Insoluble residue is shown as per cent I.R. The indicated coarser detrital content of the shales was determined by microscopic study and is shown after the I.R. The conchostracan generation (discussed and defined elsewhere in this paper) is indicated by "Gen." followed by the appropriate numeral. Species and subspecies of conchostracans are listed for each surface on which they occurred).

Bed No.			Inches
	Blk., brn.-to-lt. brn. silty soil		
8	Shale, arbitrarily subdivided into five units, given from youngest to oldest:		
	(a) plastic gy. clay, upper surface forms sharp irreg. contact with overlying soil. I.R. 69.4%; chitinous and siliceous arthropod molts and fragments of molts; marcasite flakes; sand and silt-size detrital qtz.; sand grains contaminant from overlying soil	1.25″	
	(b) waxy, blocky sh., I.R. 61.5%, well rounded silt-size detrital qtz.	3.00″	
	(c) calc. partg., limonitic crust, I.R. 16.5%, selenite xtal, well-rounded qtz. silt	0.18″	
	(d) blocky, waxy brn.-gy., highly calc. sh. I.R. 45.0%, abundant calc.-chitinous molt and shell fragments, same as in bed 7 (b), gypsum xtals	1.25″	
	(e) same as 8 (c)	0.18″	5.86
7	(a) Blue-gy. argillaceous ls.; upper surface weathers lt. blue-gy. and in small polygonal concretions; undersurface dense with conchostracans (Gen. X) *Isaura* (*Euestheria*) *harveyi A* and *B*, *I.* (*Eu.*) *harveyi harveyi*, I.R. 36.2%; large chitinous crustacean molt fragments and silicified molts; selenite xtals; apatite grain; subang.-to-subround silt size detrital qtz., clear, cloudy, and pitted; iron oxide clumps		1.50
	(b) Lithology same as 7a; top surface contains conchostracan Gen. X; undersurface contains Gen. IX, *I.* (*Eu.*) *harveyi A* and *B*, *I.* (*Eu.*) *harveyi harveyi*, I.R. 39.5%, rare marcasite slivers, gypsum xtals, abundant		

Bed No.		Inches
	large calcareous-chitinous and siliceous molts and molt-fragments; very distinctive residue due to yellow stain on molts	0.12 (0.18)
	(c) Lithology same as 7a; upper surface contains conchostracan Gen. IX; median surface, Gen. VIII, *I. (Eu.) harveyi A;* undersurface, Gen. VII, *I. (Eu.) harveyi A* anf *B, I. (Eu.) harveyi harveyi,* I.R. 48.1%, chitinous molt fragments, evaporite xtals	0.31
	(d) Lithology same as 7a; upper surface contains conchostracan Gen. VII, undersurface, Gen. VI, *I. (Eu.) harveyi A* and *B, I. (Eu.) harveyi harveyi,* I.R. 38.5%, marcasite-speckled silicified crusts, rare silicified molt fragments, evaporite xtals	0.75
6	Med. bedded lt. blue-gy. argill. ls.; undersurface peeling off in thin sheets; upper surface contains no conchostracan valves; undersurface bears valves of Gen. V, *I. (Eu.) harveyi B.* Relief of undersurface flat with long depressions. I.R. 40.8%, silicified and chitinous molts. Between this bed and next underlying, there occurs a $\frac{1}{16}$"–$\frac{1}{4}$" calc. sh. ptg. bearing conchostracan Gen. IV, *I. (Eu.) harveyi A* and *B, I. (Eu.) harveyi harveyi*	0.75
5	Dk. blue-gy. argill. ls., upper surface contains a few conchostracan valves of Gen. IV. A short distance below upper surface, valves of Gen. III occur, *I. (Eu.) harveyi A* and *B, I. (Eu.) harveyi wellingtoni, I. (Eu.) harveyi leonardii;* undersurface dense with conchostracan valves of Gen. II, *I. (Eu.) harveyi A* and *B, I. (Eu.) harveyi wellingtoni,* I.R. 38.6%, numerous arthropod chitinous molts, some silicified molts, detrital silt and evaporite xtals	0.37
4	Lithology same as bed 5; upper surface bears conchostracan Gen. II; undersurface bears Gen. I, *I. (Eu.) harveyi A* and *B,* I.R. 43.0%, arthropod silicified and chitinous molts; a single ostracod valve	0.10
3	Dk. blue-gy. calc. shale; upper surface bears limonitic stain; undersurface contains coarse zone of very small bk. shale chips, I.R. 53.0%, gypsum xtals., iron oxide cluster	0.37
2	Lithology same as bed 3; upper surface bears coarse zone as in bottom of bed 3, which grades down into bed 1; I.R. 43.0%	0.37
1	Shale, arbitrarily subdivided into 8 units	32.25
	(a) blk.-gy. platy sh., contains lt.-gy. elongated calc. sh. pebbles (of same lithology as in overlying beds 2 and 3), I.R. 70% — 4.50"	
	(b) lt. gy.-grn. plastic cly., I.R. 68.0%, some gypsum xtals — 0.75"	
	(c) blk. platy sh., same as bed 1a, I.R. 84.0% — 2.30"	
	(d) gy.-brn. plastic cly., I.R. 75.0% — 1.50"	
	(e) blk.-gy. platy sh., same as bed 1c, I.R. 84.0% (included in thickness of bed 1d).	
	(f) xtal. calc. ptgs., upper portion plastic cly., I.R. 30% — 1.20"	
	(g) blocky, waxy sh., gy.-grn., very moist, forms sharp contact with underlying bed, I.R. 55.0%, some detrital qtz. silt — 12.00"	
	(h) silty, fissile calc. sh. grading down into blocky, blk.-gy. and waxy sh., and interbedded with platy blk. waxy sh. The platy sh. is on the creek floor; the blk. platy shale contains numerous white barite xtals, I.R. 32.5%, rare grains of rounded fine qtz. sand.	
	Total measured thickness	42.75" (3.56')

PALEOECOLOGY

Conditions of sedimentation.—The lower shale unit (bed no. 1) consisting primarily of black platy shale, is not one homogeneous lithologic unit. Conditions suitable for deposition of black-to-dark gray, unstructured clay muds, may be viewed as generally persistent through the time represented by the total thickness of the basal bed. However, changes in environment did occur during this interval, as evidenced by silty, fissile calcareous shale (bed 1h), waxy, gray-green shale (bed 1g), crystalline calcareous parting (bed 1f); and the presence of light gray elongated calcareous pebbles (bed 1a).

It is important also to note that almost three feet of section of a total thickness of three and one-half feet is represented by the bottom shale. Thus, most of the life of this shallow pond (?—no information is available on the areal extent of these individual fresh water basins—present field work is directed to this end) was characterized by an influx of clay mud accompanied by resulting turbidity. During all of this time conchostracans and all other animals with hard parts were apparently absent. This is shown

by careful megascopic study of the shale horizons which revealed no valves, shell fragments, or impressions of organic individuals of any kind. Microscopic study of the shales before disaggregation gave the same result. Insoluble residue did not reveal any non-calcareous skeletal material either siliceous or chitinous.

We are then led to conclude that the conditions of sedimentation and/or of chemical events on the bottom may have prohibited the appearance, growth, and preservation of animal and plant life. The gray-green and black-gray platy shales suggest temporary reducing conditions and the presence of some carbonaceous matter. The presence of organic matter is further confirmed by the waxy shales. It thus appears likely that this pond was inhabited by numerous minute, soft-bodied forms (Protozoa, Algae) that ultimately dispersed as organic debris.

There must have been conditions in this basin (prior to bed 1a time) where light-gray calcareous muds were exposed and spottily distributed in patches amidst darker clay on the bottom. Probably this occurred during a seasonal desiccation. Subsequent erosion and brief transportation would account for the calcareous shale pebbles incorporated in the black-gray platy shale of bed 1a. Subsequently (during the times of deposition of beds 2 and 3), the situation was reversed. That is, patches of dried-up black gray mud bottom eroded to form the coarse shale-chip zone in these lighter shale beds. (Further conditions of sedimentation are discussed in different contexts under other subheadings).

FAUNAL ASSOCIATES OF THE CONCHOSTRACANS

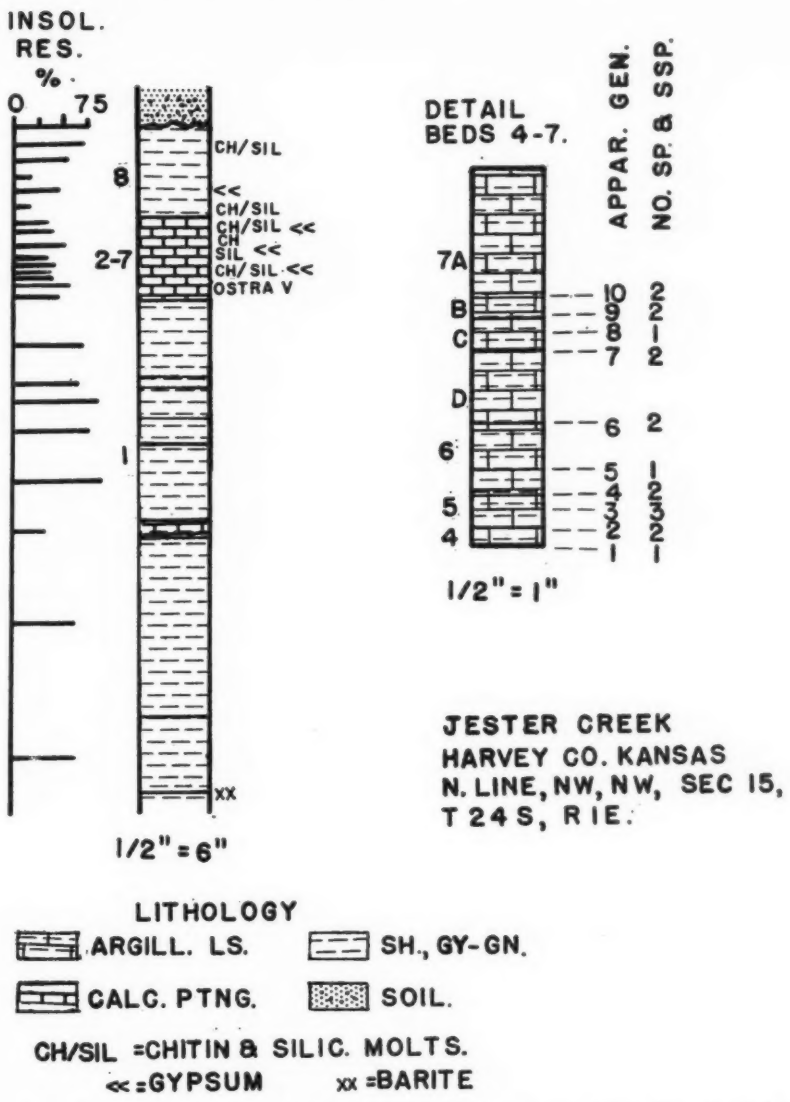
Conchostracans first appeared in the section (undersurface of bed 4) represented by both forms A and B of the new species described under Systematic Paleontology. Also, the insoluble residues of this horizon reveal the first arthropod chitinous and siliceous molts found in the section. This evidence indicates that other small-sized arthropods including insects co-inhabited this pond along with the clam shrimps. Furthermore, they persisted after the apparent last appearance of the clam shrimps (i.e., they are found in insoluble residues from horizons above bed 7a).

An ellipitical, relatively large (L = 1.325 mm., H = 0.775 mm.) silicified detached ostracod valve occurred in the residue of bed 4. The tuberculate convex surface bears discrete minute closely-spaced grains that can be seen as a granular fringe girdling the valve on the reverse side. It does not resemble any of the Permian fresh-water species so far reported (Scott, 1944, pls. 23, 24). Larger samples are being run for insoluble residues in the hope of recovering more valves. But even this single, as yet unidentified, valve, indicates that some ostracods were among the faunal associates of the conchostracans in this pond.

INSOLUBLE RESIDUES AND CARBONATE FRACTION

The apparent initial appearance of the clam shrimps in this section coincided with the lithologic and corresponding chemical change from a calcareous clay mud bottom to an argillaceous lime mud bottom (Text-fig. 1). The carbonate content increased by ten percent from bed 3 to bed 4. The carbonate fraction also varied above and below this figure during the times of successive conchostracan generations. In the highest bed (bed 7a) in which clam shrimps were found, there was almost a twenty per cent higher carbonate content than in bed 3. On the other hand, carbonate content decreased by nearly ten percent after the clam shrimps no longer were found in the section (bed 8d).

It is obvious that carbonate content was not the only critical, or even a direct, factor in conchostracan appearance or growth. Thus, in the lower shale unit (bed 1h) where high carbonate content occurs, no clam shrimp fossils were found. There are several considerations needed to arrive at an appreciation of the influence of variable carbonate content. First, we need to recall that living estheriid conchostracans are burrowers in bottom muds (Pearse, 1945:665), although they do move above the bottoms (Mathias, 1937:19). Second, as burrowers, they obtain food from organic debris in bottom muds. This debris is derived from protozoans, rotifers, diatoms, and algae (Mathias, 1937:29; Pennak, 1953:332–333; Pearse, 1945:665–666). Occasional species have been



TEXT-FIG. 1—Columnar section and detail of Jester Creek section. *Insol. Res.*, insoluble residue; *Appar. Gen.*, apparent generation; *No. sp. & ssp.*, number of species and subspecies. Detail shows only conchostracan bed.

observed eating minute entomostracans. Third, the carbonate content is unlikely to be related to the secretion of hard parts since conchostracan valves are chitinous with an inner membranous lining (Sars, 1896) and are only slightly calcified (Mathias, 1937:4).

When these factors are reviewed, it seems plausible to conclude that carbonate content is in some way related to food supply. Certain other critical trace elements associated with calcium may have been important to the growth and flourishing of microscopic soft-bodied plankton inhabiting the pond. In turn, a relationship of this kind

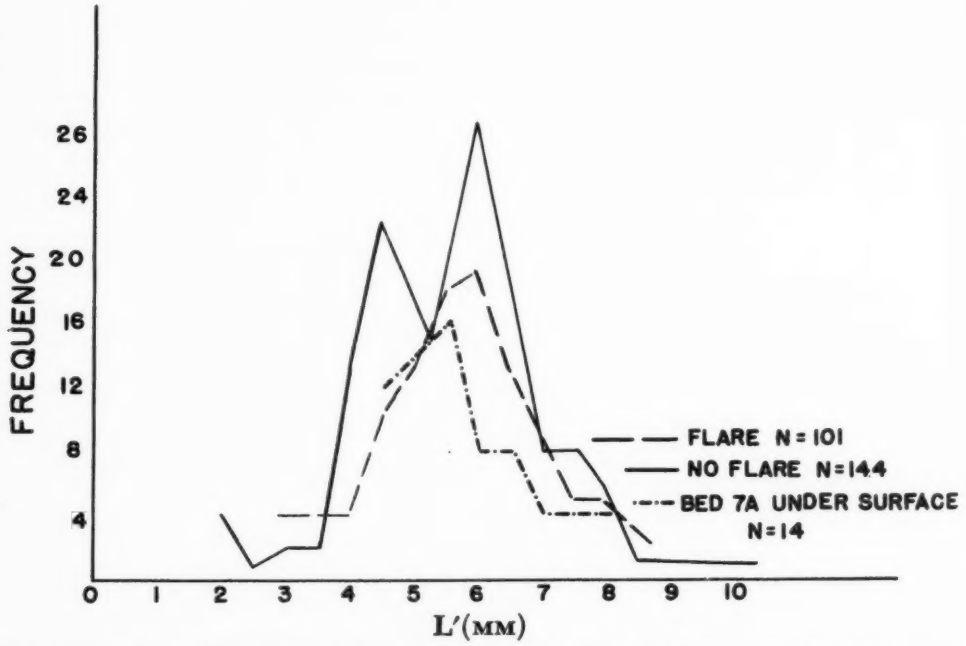
would ultimately correlate with the amount of organic debris available in the bottom muds for conchostracan consumption.

ARTHROPOD MOLTS

The presence of as yet unidentified molts of other arthropods (including insects) during and after the time conchostracans inhabited the pond, may indicate a predator-prey relationship (cf. Mathias, 1937:72–74). While several reasons can explain the fact that conchostracans were not found above bed 7a, one such reason could be a relationship of this kind. This speculation can be tested. In bed 7a, the last time conchostracans appeared in the section, we would expect to find the larger valves of reproductively mature individuals and few or none of newly hatched larvae or immature growth stages. Text-figure 2 shows a shift to the right in the curve for valves (flare and no-flare valves are combined, since only the size is important here) found on the undersurface of bed 7a. In other words, although a reproductively mature population is represented, the clutches of eggs released by females either never hatched or were consumed shortly after hatching. Hence, no generation succeeded the one found at this horizon. An alternative possibility is that a predator-prey relationship existed between the pond insects and larval forms of other soft-bodied forms. If so, the food supply in the bottom muds was depleted or so diminished that newly hatched clam shrimps could not continue growth.

Whatever the explanation, the absence of all immature stages prior to the disappearance of clam shrimps from the pond is a fact. The parallel first appearance of the arthropod molts with the first appearance of the clam shrimps and the continued occurrence of such molts after the disappearance of the clam shrimps in the section is likewise a fact.

Lithologically, the upper and lower shale units are quite similar. That would denote relatively uniform conditions of sedimenta-



TEXT-FIG. 2—Graph of *Isaura* (*Euestheria*) *harveyi*, Form A (flare) and Form B (no flare). *L'*, greatest length of valve as measured by a line bisecting the umbonal angle. Curve for valves on Bed 7a includes both flare and no flare types of the new species which are separately graphed for the rest of the population. Peaks correspond to growth stages. Note shift of Bed 7a curve to the right as constrasted with the other two curves.

tion pre- and post the conchostracan occurrences. The decrease in carbonate content, as noted earlier, and the continuance of the arthropod molts in the upper shale may be the two clues to conchostracan demise.

SUCCESSION OF CONCHOSTRACAN GENERATIONS AND THE RATE OF SEDIMENTATION

Paired Surfaces.—Reference to text-figure 1 will indicate a column to the right of the "detail" labelled "apparent generations," i.e., a 3.90 inch thick argillaceous limestone from bottom to top bore twenty distinct surfaces or ten pairs of surfaces. These occurred where the rock naturally parted along planes of weakness created by strewn conchostracan valves (internal molds). These were positioned either concave or convex upward on the basal surface of any given pair while the overlying surface bore mostly impressions of the basal valves. In addition, some internal molds not occurring on the basal surface were incorporated in the overlying surface.

Each two complimentary surfaces of this kind, i.e., a pair, is interpreted to represent one and the same apparent conchostracan generation. Only the first appearance of clam shrimps in the section, bed 4, did not show a pair of surfaces but merely the fossil strewn undersurface of bed 4, with the top surface of underlying bed 3 barren. Hence the initial occurrence which is designated "apparent generation number 1" does not refer to a "pair" of surfaces.

Such conchostracan-covered surfaces occurred at short intervals but are nonetheless separated in time (i.e., the time to deposit the sediment from the undersurface bearing conchostracans to the time the conchostracans on the upper surface appeared). The undersurfaces of successive slabs repeat the fauna of the next underlying top surface and, as noted above, are considered a pair and the *same* generation is listed for each such pair (cf. Text-fig. 1 and Table 1). It might be noted that the rock weathers out as slabs or sheets that can readily be removed.

Data of Fresh Water Biology Applied.—The concept of conchostracan generations derives from studies of modern estheriid branchiopods. If the clam shrimps inhabit small ponds that contain water for only a few weeks during spring and early summer, there will usually be one generation per year. If, however, the ponds are permanent or of longer duration, months instead of weeks, there can be more than one generation per year. (Pennak, 1953:337–338). Study of Table 1 indicates that the Jester Creek water body was most likely seasonally dried up. If this were not so one would expect a greater number of conchostracan-bearing surfaces ("surfaces" as defined above) in the same thickness of sediment.

TABLE 1—NUMBER OF APPARENT CONCHOSTRACAN GENERATIONS, SPECIES AND SUBSPECIES, AND THICKNESS OF SEDIMENT BETWEEN SUCCESSIVE GENERATIONS

(1) Bed Number	(2) Subdivision	(3) Thickness of Sediment ($\times \frac{1}{16}$")	(4) Number of Apparent Generations	(5) Number of different species and subspecies represented as distinct generations
VII	A	8.0	1	—
	B	1.5	1	2
	C	6.5	2*	3
	D	9.5	1	2
VI	—	14.0	1	1
V	A	3.0	1	2
	B	3.0	1	3
IV	—	3.0	1	2
III	—	5.5	1	3
Total		54.0	10	18

* There is an intermediate surface on this slab bearing conchostracans. It is separated from the fossils on the undersurface and top surface of the same slab.

Table 1 also shows that the least thickness of sediment separating two generations of conchostracans was 1.5/16" while the greatest thickness was 14/16" with 3/16" the most frequent. If we assume the least thickness as the plausible average, then for the total thickness of conchostracan-bearing beds (3.90"), forty-three distinct generations would have been possible in the time represented. Actually, less than half that number were found. Thus, multiple generations within the same year seem unlikely.

Even on the assumption of one generation per year, certain qualifications are required Living conchostracans are known to complete their life histories (from hatching to

death) in about one month (*Lynceus brachyurus* Müller) (Mattox, 1939:645–646) or egg-to-egg cycle in twenty-three days (*Eulimnadia stoningtonensis* Berry) (Berry, 1926:429–433). A two month history appears to characterize *Cyzicus mexicanus* (Claus) (Pennak's interpretation of Mattox' data, *see* Mattox, 1939, *op. cit.*) While one to two months seems to be the range of such histories, it is well to bear in mind that some conchostracans can survive under natural conditions for as high as six months, as for example, *Caenestheriella gynecia* Mattox (Mattox, 1950:50–53). We may therefore expect different species of *Cyzicus* (=*Isaura* s.s.) will have life cycles that vary somewhat below and above this general range. Such variation, however, will not be large. Life cycles of estheriids known only as fossils can also be placed within such limits.

It follows from the above that the Jester Creek specimens from any "apparent" generation represent individuals at varying stages of growth (cf. Text-fig. 2). The larger individuals will have completed their life cycle while the smaller will have died at some intermediate stage. The succession of generations of the same species and subspecies (see "detail" Text-fig. 1) makes it clear that starting from generation 1, many individuals did attain sexual maturity.

Under the *Systematic Descriptions* two distinct forms of the new species are discussed. It is suggested that since they differ in a single morphologic character, i.e., presence or absence of a flare (see Plate 1), they may represent females and males respectively. Both forms always occur together in the section. At any rate, eggs released by the females somewhere during a two months' growth cycle would become incorporated in the bottom muds when the ponds seasonally dried up. Hatching would have occurred when the ponds filled up during the next season.

However, limnologists point out that the same modern branchiopod species may either recur annually in a given pond or sporadically after a lapse of years. Then too, it has been observed that in such temporary ponds it is rare to find more than a single species of a given conchostracan genus. These observations taken together can help to explain an anomaly in the conchostracan faunal occurrence in the Jester Creek section.

One new species and three subspecies are recognized in this fauna. Subspeciation is the anomaly. How can this be explained if several subspecies and the parent species all occur on the same surfaces and thus belong to the same apparent generation? It has long been known that subspeciation involves geographic isolation of smaller populations from the parent population. It also implies a substantial supply of genetic material which can undergo physical and chemical changes and thus lead to the observed morphologic distinctiveness of the subspecies. For branchiopods, the supply of genetic material is certainly adequate. Observations on living forms indicate that females yield from one to six clutches each with ten to twenty eggs per clutch in intervals of two to six days (Pennak, 1953:329, fig. 205c; 334). While detailed statistics are not available on the reproduction of living conchostracans, the figures cited above apply to the Eubranchiopoda in general and are thus relevant.

Because of the short interval of time separating the release of one clutch from another, we may view all eggs released as contemporaneous. The opportunities for geographic isolation in a shallow pond that was probably very limited in extent seem to have been quite small. Living phyllopods are usually found in water bodies about one acre in area (Pennak, 1953:337). In such a body of water, bottom currents that might facilitate distribution would also have been absent or negligible. Thus, subspeciation in the Jester Creek section would have to be accounted for in some other way.

Multiple Generations per Surface.—On any given surface bearing conchostracans a plane tangent to all valves cannot be passed. That is to say, there is relief, although it is very meager. Some valves are slightly higher on the surface than others. Suppose then, that it is assumed that more than one generation is present on a given surface where parent species, and subspecies both occur. Then the observed relief, however minor, could be accounted for by the negligible accumulation of sediment over several seasons (years). If so, surfaces bearing more than one subspecies could be in-

terpreted as representing one distinct season or year for each subspecies and species found. In other words, they are apparently the same generation but, having lived during successive seasons, are in reality multiple generations. As such, the number of years represented on any surface can then be read.

Reasoning in this way, one arrives at the figure of a total of eighteen generations on the ten paired surfaces rather than the apparent ten (see "detail" Text-fig. 1). Before it was recognized that there were two forms of the new species, each was designated as a separate species in a preliminary report (Tasch, 1957). This led to a figure of twenty-four generations. However, analysis of numerical data showed that both forms belonged to the same species. The figure of eighteen generations is therefore a more accurate estimate.

The thickness of sediment accumulating between the times of any two generations would be 0.04″. This figure is obtained from Table 1 using the lowest figures. The total thickness of the fossiliferous beds is 3.90 inches. This figure may be divided by the derived annual rate of sedimentation, 0.04″. The result indicates the probable time it took to deposit the blue-gray argillaceous muds bearing the eighteen conchostracan generations. The figure is 97.5 years or approximately one century.

This figure is admittedly an approximation structured on a particular chain of assumptions. Nevertheless, reference magnitudes of this kind are distinct aids to the geologist and can be refined or revised as our knowledge improves. It seems prudent to allow a correction factor of plus or minus fifty years to accommodate factors that may have been operative but which were not taken into account in the chain of assumptions. Thus, 100 ± 50 years is the estimated time of deposition.

An annual sedimentation rate of 0.04″ would, in fact, be unobservable on a given conchostracan-bearing surface. The meager relief of such surfaces could readily accommodate a few such increments over several years.

SUBSPECIATION

Although subspeciation has already been mentioned in another context, it requires further consideration. Form A of the dominant species *I.* (*Eu.*) *harveyi* bears a narrow flare which may be a sexual character. One can cite a parallel in the ostracode genus *Hollinella* as redefined by Kellett, where frilled and unfrilled forms occur. In this instance, the frilled forms were interpreted as mature females.

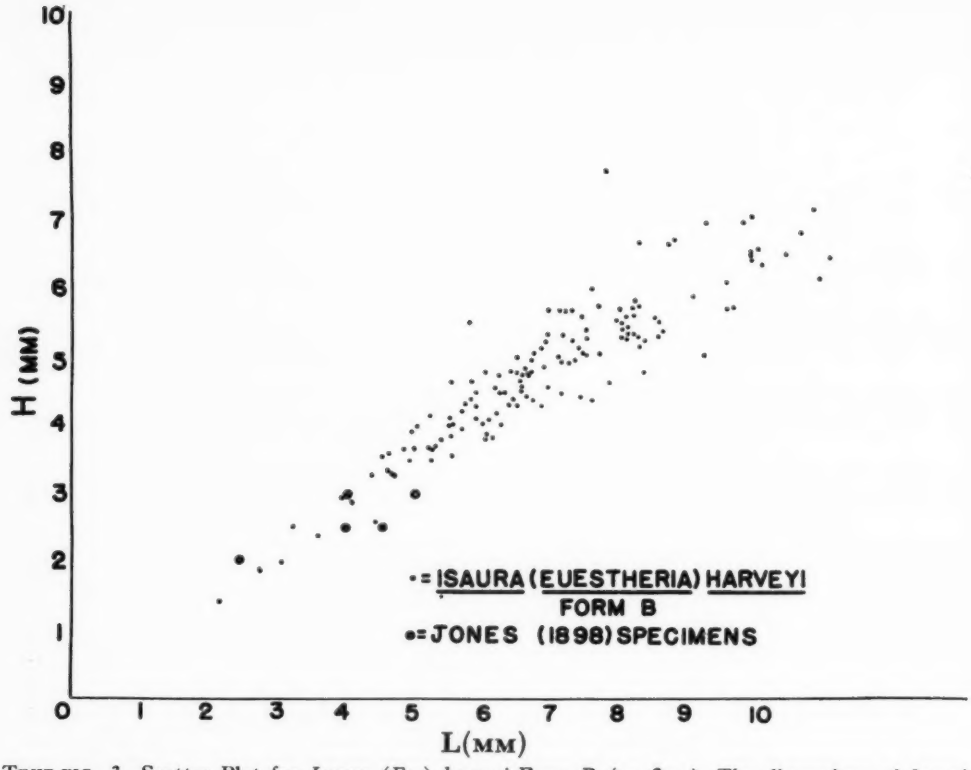
Whatever sex the flared forms denote in the present example, it appears that in genetic terms "flare" is a sex-linked character. No evidence of subspeciation was observed in unflared specimens.

The nature of the variability in the character "flare" is of interest. In the parent species "flare" occurs as a narrow, flat area that starts on the posterior flank of the umbo (see Pl. 1, figs. 1a,1d). The width of the flat area varies from a mere dorsal groove (Pl. 1, fig. 1c.) to a perceptibly wider zone (Pl. 1, fig. 1d). Within these limits fall the "flare" in all specimens of Form A of the parent species.

In the subspecies *I.* (*Eu.*) *harveyi harveyi* (Pl. 2, fig. 2a) a distinct widening of the "flare" occurs. This widening cannot be dismissed as being part of the range of width-variation of Form A. When examining the valves that crowded any given surface, wide-flare types were immediately distinguishable from the more numerous narrow-flared valves. The wider flare proceeds much further down the posterior side of the valve and has a more pronounced inner curvature where it is in contact with the convex portion of the shell.

While it is likely that the Form A individuals with the widest of the "narrow" flares were the ancestral stock of this new subspecies, selection and genetic change appear to have been the prerequisites for the appearance of the wide-flare subspecies.

Another very distinct modification in "flare" types of the parent population is the appearance of a flare that proceeds over and behind the umbo (Pl. 1, figs. 3a,b, cf. Pl. 1, fig. 1a). This new subspecies *I.* (*Eu.*) *harveyi wellingtoni* cannot be dismissed as a mere end member in the normal distribution curve of the character "flare" for the parent population. The umbonal position itself is a very critical feature of conchostracan classification (Tasch, 1956, and ms.) When this



TEXT-FIG. 3—Scatter Plot for *Isaura* (*Eu.*) *harveyi* Form B (no flare). The dimensions of Jones' (1898) specimens of *Estheria minuta* were superimposed on this plot and support the conclusion that they belong to Form B of the new species. *L*, length as measured across valve from anterior to posterior; *H*, height as measured from ventral to dorsal.

position has been changed from the condition "rising above the dorsal margin" to being "below the dorsal margin" due to spread of "flare" behind it, genetical changes seem to be indicated.

The final variation in "flare" is found in a single valve of a new subspecies *I.* (*Eu.*) *harveyi harveyi* (Pl. 4, fig. 4). Here a wide-type posterior flare and a very narrow anterior flare occur with the umbo rising above both flares.

MEASUREMENTS AND GRAPHIC ANALYSIS

Some 300 separate camera lucida drawings were prepared from internal molds of conchostracan valves. The valves on each slab were numbered. Of these drawings, 278 were used for graphic analysis.

Angles were measured with a precision protractor. Six direct measurements were made on each camera lucida drawing and later corrected for magnification. These included l', w, h, l, as well as the umbonal angle θ and the postero-dorsal angle β.

Of these, the angular measures were found not to be discriminatory intra-species and subspecies, although they may prove valuable for interspecific comparisons. The usual length-height measures of a given valve represent the maximum length from anterior to posterior and greatest height from ventral to dorsal. These measures were also used in this study but only for comparative purposes. (see Text-fig. 3). In actuality, the measures that when graphed represent the closest approximation of true growth trend of the population, are those that have a vectorial property implied. That is, the measure l' used in this study is a line that bisects the umbonal angle θ and extends across the maximum shell expansion as well as in the actual direction in which the shell

grew. Similarly, the measure *w* is drawn tangent to that growth line which in position corresponds to the plane of maximum anterior-posterior expansion of the valve. Thus, the pair of measures *l'* and *w*, as defined, are not an indirect report of relative valve growth as are the usual *l* and *h* measures. Rather, as one studies text-figure 4, the direction of shell expansion is directly discernible.

Text-figure 4 shows that the two forms of the new species, flare and no flare, have overlapping point distributions and similar growth characteristics when measures *l'* and *w* are used. Without regard to form, the scatter shows that the range 0–8.0 mm. for *l'* and 0–10.0 mm. for *w* embraces most of the population. Beyond this range few points occur. Similarly, few points occur slightly below 4.0 mm. for both *l'* and *w*. These two areas of the scatter represent the late adult and early growth stages respectively.

For further insight into the growth stages, a plot of *l'* against frequency shows polymodality (Text-fig. 2). The peaks at 2.5 mm. and 3.0 mm. suggest that at least two of the later juvenile stages and none of the earliest are present. The graph then shows a broad spread which would correspond to the bulk of the sexually mature population. The twin peaks here may separate adolescent from adult stages. The upper flat sector on the graph might have appeared as a minor peak if a larger sample were available. As such, it may denote a distinct group of non-reproductive adults within the normal reproducing population. This interpretation is supported by an equivalent flat sector for the "flare" type as well as for the "no flare" type and is especially meaningful if "flare" is a sex-linked character as the present writer surmises it may be.

SYSTEMATIC PALEONTOLOGY

Family ISAURIIDAE Bock 1953, emend. Tasch 1955

ISAURA (EUSTHERIA) HARVEYI Tasch, n. sp.
Pl. 79, figs. 1a-d

Estheria minuta (Alberti) Jones, 1898, p. 292, text-figs. 1–4.

Isaura (*Euestheria*) species A; B; C Tasch, 1957, Kans. Acad. Sci. Trans. *in press*. Pl. 1, figs. A–C.

Description.—Valves ovate to oblong, convexity most strongly expressed in umbonal region; dorsal margin usually straight but may be gently arched, antero-dorsal margin straight, oblique to dorsal margin or roundly curved; ventral margin elliptical or sub-oval curvature; postero-dorsal margin straight or oblique to dorsal margin or oval curved. Umbo subterminal.

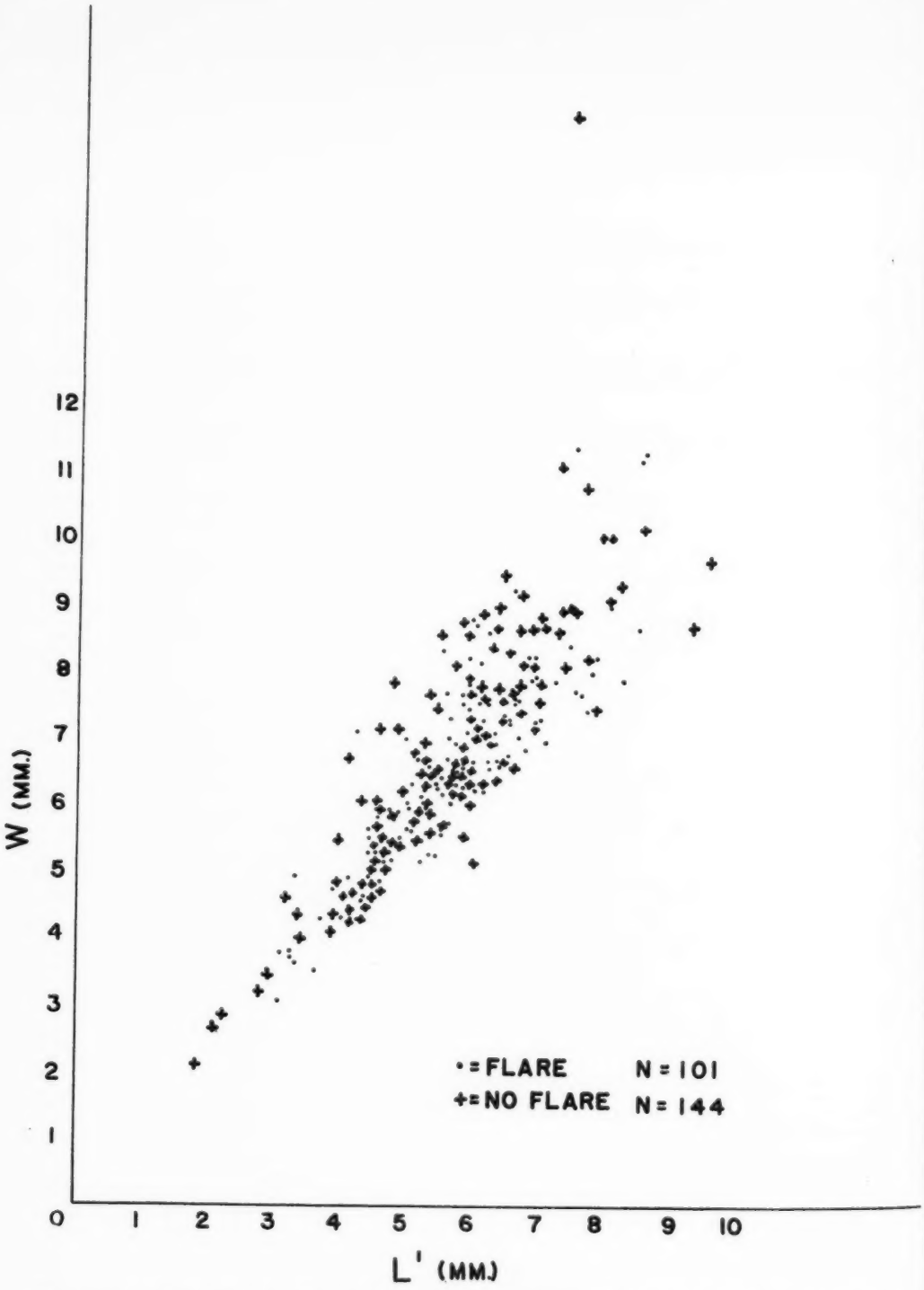
Two variants are distinguished. These are designated "forms." Form A has a flare. Form B lacks a flare. In all other respects the two forms share the same specific characters.

Preservation of the internal molds of this species does not reveal any ornamentation other than sporadic punctuation in the intervales. The growth lines are generally round or curved and show a shingle type weathering. Number of growth lines variable, maximum counted was 26; umbonal growth lines, maximum counted was 14, minimum, 5; spacing of growth lines variable from one specimen to another.

Discussion.—The flare is not a structure such as costae, for example. Rather, it is a narrow, flat area of the valve that occurs directly below the dorsal margin and variably expands postero-dorsally from the flank of or behind the umbo. This area contrasts with the general convexity of the rest of the valve. All growth lines cross it. Occasional individuals show the flare so slightly expanded that it appears as a groove parallel to the dorsal margin (Pl. 1, fig. 1c). In a few individuals the more dorsal portion of the umbo is included in the flattened area.

Form B has valves showing unrelieved convexity in the area where Form A individuals show a flattening. It is possible that the absence or presence of a flat flare is a sexual character. If so, the ratio of the sexes in this sample is approximately $1\frac{1}{2}:1$.

The flat flare is interpreted to be a genetically determined character because of its marked distinctness, its widespread occurrence, and its uniformity within the group in which it occurs. It can readily be distinguished from flattening due to compaction, pressure or crushing, since this type occurs at random, lacks uniformity of expression, etc. Furthermore, it has been possible to differentiate several subspecies on the basis of modification of the flare.



TEXT-FIG. *4*—Scatter Plot for *Isaura* (*Eu.*) *harveyi* Form A (flare) and Form B (no flare). *L'*, greatest length of valve as measured by a line bisecting umbonal angle. *W*, maximum width as measured by a line tangent to a growth line along plane of greatest anterior-posterior expansion of the valve. The point scatter for each form overlaps the other and indicates that they belong to the same species. The valve character "flare" is thought to be sex-linked and may distinguish the valves of females.

The only estheriid-type concostracans previously described from Kansas were specimens sent to Jones (1898, figs. 1–4). These were from Sumner County Permian red beds. They were assigned to *Estheria* (=*Isaura*) ***minuta***. It is likely that Jones' specimens (Idem., figs. 2, 3) belong to Form B of the present species (see Text-fig. 3). We may exclude it from *Isaura* ***minuta*** because of the following: the less pronounced umbo which in *I.* ***minuta*** is more pointed and higher above the dorsal margin, the absence of polygonal ornamentation which is characteristic of *I.* ***minuta***. Form B of the new species described here is also distinct from *I.* ***minuta*** in these features.

Dimensions.—Critical dimensions of the two figured specimens of the syntype are:

Bed	Spec. No.	Umbonal angle (degrees)	Length (l′) (mm.)	Width (w) (mm.)	l′/w	Number of growth lines	
						Umbo	Total
7c*	5	131.7	5.71	6.38	.896	6	14
7a*	2	134.0	6.33	7.86	.806	14	21

* Bottom.

Text-figs. 2–4 show graphically the characteristics of the entire sample. The significance of these graphs is discussed in the text.

Types.—Syntype: W.U. 100.2A, W.U. 100.2Ap, W.U. 100.2B, W.U. 100.2Ap′ (These, and all other types described, as well as the entire sample are on deposit in the Dept. of Geology, University of Wichita).

ISAURA (EUESTHERIA) HARVEYI HARVEYI Tasch n. subsp.
Pl. 79, fig. 2a,b

Isaura (*Eu.*) sp. E Tasch, 1957, Kans. Acad. Sci. Trans. ***in press***, pl. 1, fig. E.

Description.—This subspecies is like *Isaura* (*Eu.*) ***harveyi*** in all respects except in the more pronounced width of the flare. It ranges to as much as twice the flare-width of the parent species. In many specimens, the wider flare includes the more dorsal portion of the umbo.

Discussion.—The sample (n = 30) appears to represent a portion of the *I.* (*Eu.*) ***harveyi*** population which was not yet completely reproductively isolated. This is shown in the morphologic similarity in other respects than width of flare (cf. Text-fig. 5). Taxonomically, this is a distinctive carapace feature.

Dimensions.—Critical dimensions of the two figured specimens are given at the bottom of this page.

Types.—Holotype, W.U. 100.21; paratype, W.U. 100.21p′.

ISAURA (EUESTHERIA) HARVEYI WELLINGTONI Tasch, n. subsp.
Pl. 79, fig. 3a,b

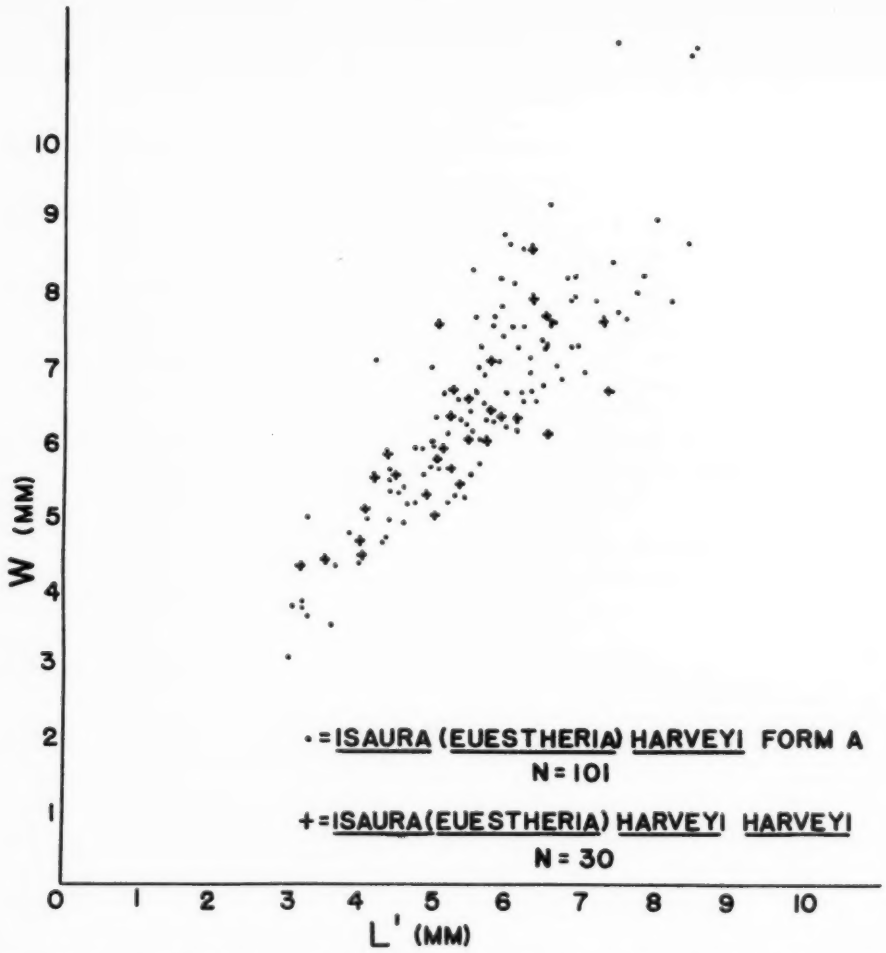
Isaura (*Eu.*) sp. *E″* Tasch, 1957, Kans. Acad. Sci. Trans. ***in press***, pl. 1, fig. E″.

Description.—This subspecies has the characteristic dorsal-posterior expanding wide, flat flare of *I.* (*Eu.*) ***harveyi harveyi***. In addition, it bears a groove-like dorsal continuation of the flare behind the umbo.

Discussion.—The present author recognizes the absurdity of designating each variant of a species by a separate name. Nevertheless, this subspecies is so distinctive on the slabs that also contain *I.* (*Eu.*) ***harveyi*** and *I.* (*Eu.*) ***harveyi harveyi***, that it seems desirable to signalize this difference.

It was noted that in the parent species a

Bed	Spec. No.	Umbonal angle (degrees)	Length (l′) (mm.)	Width (w) (mm.)	l′/w
3d, bottom	11	121.2	4.29	5.52	0.776
4, bottom	25	98.3	6.57	6.19	1.062



TEXT-FIG. 5—Scatter Plot for *Isaura* (*Eu.*) *harveyi* Form A and the subspecies *I.* (*Eu.*) *harveyi harveyi*. Form A specimens are characterized by a "narrow" flare; the new subspecies by a "wide" flare. The point scatter indicates that it would not be possible to distinguish the subspecies from the parent species in terms of L' and W. (These measures are defined in the legend for Text-fig. 4.)

pseudo-dorsal groove occurs in one specimen when the flare is so narrow as to be parallel to the dorsal margin. Again, in the subspecies *I.* (*Eu.*) *harveyi harveyi* only the wider flat flare occurs without a pseudo-groove. In the subspecies *I.* (*Eu.*) *harveyi wellingtoni* both of these carapace features are incorporated. That these three distinct variations were genetically determined appears to the present writer an observation difficult to ignore.

The classification of fossil estheriid-type conchostracans has been so confused that many distinctive forms were lumped in a single species and genus. Both with a view to clarifying evolutionary relationships and as an aid in the stratigraphic use of Leonardian conchostracans, it is deemed desirable to elevate impressive detectable morphologic differences to the rank of subspecies. This will be especially important as field work continues and populations from equivalent horizons are studied and compared with the pilot study at Jester Creek.

Dimensions.—The two specimens of this subspecies have the following dimensions:

Bed	Spec. No.	Umbonal angle (degrees)	Length (l') (mm.)	Width (w) (mm.)	l'/w
5a, bottom	14	114.9	4.71	5.62	0.839
5, bottom	45	148.0	5.24	7.14	0.733

Types.—Holotype, W.U. 100.23; paratype, W.U. 100.23p.

ISAURA (EUESTHERIA) HARVEYI LEONARDII Tasch, n. subsp.
Pl. 79, fig. 4

Isaura (*Eu.*) sp. *E'* Tasch, 1957, Kans. Acad. Sci. Trans. *in press*, pl. 1, fig. *E'*.

Description.—This subspecies differs from the parent species and the other subspecies by having a narrow anterior flare as well as the species-type posterior flat flare.

Discussion.—The ventral anterior growth lines cross the anterior flare and the entire narrow area is flattened. It should be noted that there is every evidence that the flattening is biologic and not due to compression of the valve.

Dimensions.—The single valve found had the following dimensions:

Bed	Spec. No.	Umbonal angle (degrees)	Length (l') (mm.)	Width (w) (mm.)	l'/w
5a, bottom	19	109.5	3.29	3.52	0.932

Types.—Holotype, W.U. 100.22.

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MANUSCRIPT RECEIVED DECEMBER 6, 1957.

EXPLANATION OF PLATE 79

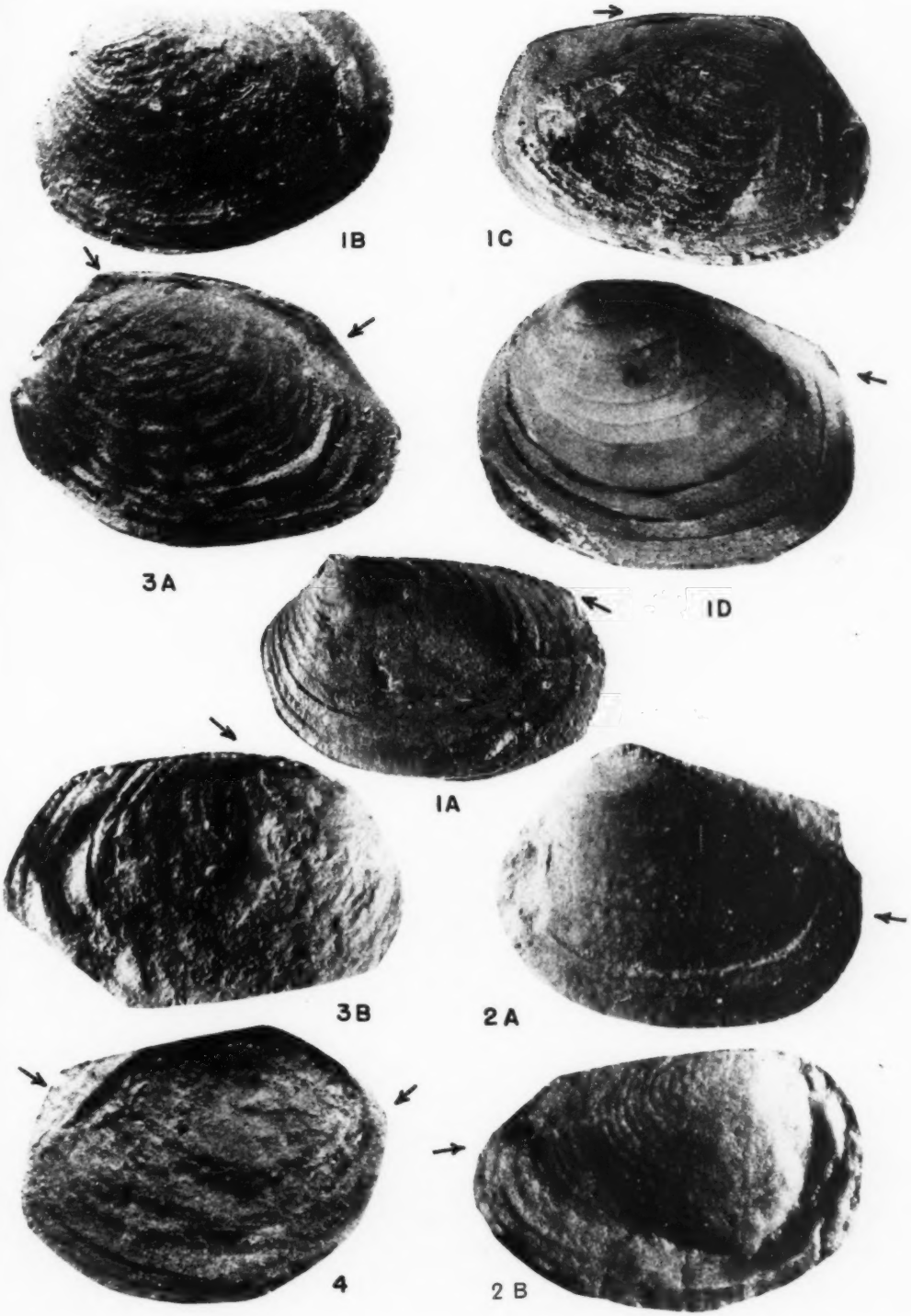
(All specimens are from the Jester Creek section and were photographed on the slabs on which they occurred. Photographs are unretouched, fossils untreated.)

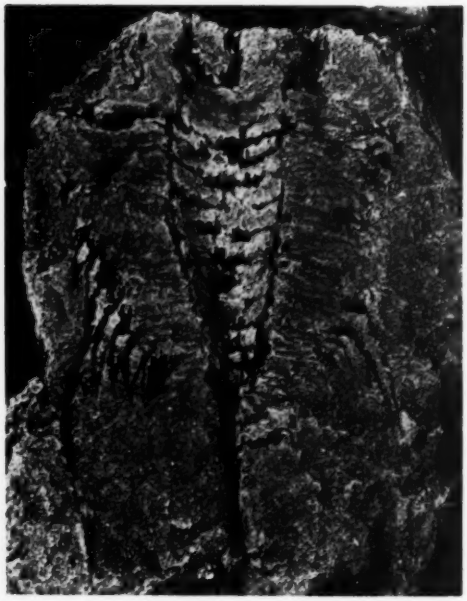
FIG. *1*—*Isaura* (*Euestheria*) *harveyi* (A) Tasch, n. sp., a, left valve of syntype, Form A, Arrow indicates narrow flattened flare, W.U. 100.2A, bed 7c, bottom surface, ×6; b, left valve of syntype, Form B, note absence of flattened flare, W.U. 100.2B, bed 7a, bottom surface, ×7; c, right valve of syntype, Form A, arrow indicates dorsal groove that terminates flattned flare, W.U. 100.2Ap, bed 7d, bottom surface, ×6; d, left valve of syntype, Form A, arrow indicates typical flattened flare, W.U. 100.2Ap′, bed 5b, top surface, ×9.

2—*Isaura* (*Euestheria*) *harveyi harveyi* Tasch, n. subsp., a, left valve of holotype, arrow indicates posterior termination of wide flattened flare, W.U. 100.21, bed 7d, bottom surface, ×11; b, right valve of paratype, plastic clay impression, arrow indicates posterior termination of wide flare, W.U. 100.21p′, bed 6, bottom surface, ×8.

3—*Isaura* (*Euestheria*) *harveyi wellingtoni* Tasch, n. subsp., a, left valve of holotype, right arrow indicates position of flattened flare; left arrow indicates continuation of flare behind umbo, W.U. 100.23, bed 5a, bottom surface, ×11; b, right valve of paratype, arrow indicates where flare continues behind the umbo, W.U. 100.23p, bed 5, bottom surface, ×8.

4—*Isaura* (*Euestheria*) *harveyi leonardii* Tasch, n. subsp., a, right valve of holotype, left arrow indicates usual *harveyi* (A)-type flare; right arrow indicates another very narrow flat anterior flare, W.U. 100.22, bed 5a, bottom surface, ×10.


1B
1C
3A
1D
1A
3B
2A
4
2B



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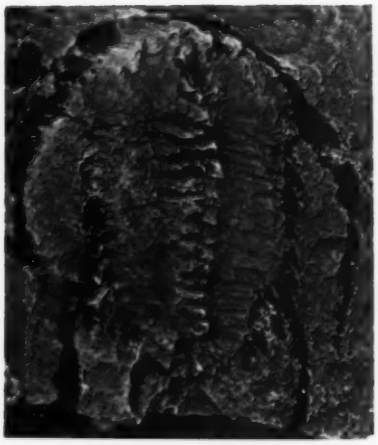

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 541–543, PL. 80, MAY 1958

LOWER TREMADOCIAN TRILOBITE FROM VENEZUELA

E. A. FREDERICKSON
University of Oklahoma

ABSTRACT—The occurrence of the trilobite species, *Parabolina argentina* in the thick sequence of "metamorphic" rocks at El Baul, Venezuela establishes the age as lower Tremadocian. Evidence of low grade metamorphism is confirmed by the distortion and shearing of the trilobite specimens. The presence of *P. argentina* in Venezuela forms one more link in the chain of developing evidence concerning the distribution of the Atlantic province Olenid fauna in Upper Cambrian and early Ordovician time.

INTRODUCTION

THE occurrence of trilobites in the Mireles formation in the El Baul region of Venezuela was first reported by Rod (1955). The age of the "metamorphic" rocks at El Baul has long been speculative. On the basis of the trilobites, Rod (1955, p. 1868) states:

> As to the age of the Mireles formation, the only statement that can be made prior to an evaluation of the trilobite fauna is that it can be definitely assigned to the Paleozoic.

Cecilia Martin Bellizzia, geologist of the Geology Department of the Ministry of Mines and Hydrocarbons of Venezuela, accomplished the geological study of the El Baul massif during the first months of 1956, as part of the geological Maps Nos. 3301 and 3304.

During her work, she collected more than 50 specimens of trilobites from the Mireles formation. These were sent to me for identification.

The trilobite specimens occur in a dark gray argillite. Rod (1955) objects to the use of the term metamorphics for these rocks and places it in italics in his article, although admitting the presence of incipient flow cleavage at many exposures.

Evidence of low grade metamorphism is provided by the trilobites which are distorted in various ways. In most cases, it is apparent that the trilobite shields were more competent in respect to the shearing stresses than the rock in which they were contained. Lineations in the trilobite shields apparently controlled the development of cleavage and shearing. This has resulted in the thoracic segments of some specimens slipping over one another like a deck of cards. In other cases the axial or longitudinal furrows of the trilobites controlled the shearing so that the trilobites have been compressed laterally, producing acute angularity of the axial and pleural lobes.

The trilobites collected from the Mireles formation are all assignable to one species, *Parabolina argentina* (Kayser). Harrington & Leanza (1957) have shown that Kayser's species *Olenus argentinus* is a senior synonym of *Parabolina andina* (Hoek), one of the most frequent and characteristic species of the lower Tremadocian of Argentina and Bolivia.

Parabolina argentina (*Olenus argentinus*) was first described from sandstone beds at Tilcuya, Bolivia (Kayser, 1867). Hoek (Steinmann & Hoek, 1912) described *P. argentina* (*Parabolinella andina*) from Salitre on the Bolivia-Argentina boundary. Kobayashi (1937) in reviewing the Cambro-Ordovician faunas of South America placed the *P. argentina* black shales of Salitre in

EXPLANATION OF PLATE 80

FIGS. *1–5*—*Parabolina argentina* (Kayser). *1*, external mold, ×4, showing natural shape of axial lobe; thoracic spine developed from 12th segment; pygidial axis missing. *2*, complete specimen, ×3; best preserved of the collection. 3, external mold, ×2, showing details of thoracic segments. *4*, specimen compressed in anterior direction, ×2. *5*, specimen illustrating lateral shearing ×2.

the Upper Cambrian (late Croixan) and the stratigraphically higher *Kainella*-bearing strata of Bolivia and Argentina in the Tremadocian.

Harrington (1938) in describing the lower Ordovician faunas of northern Argentina placed *P. argentina* in what he term the *Parabolinella* fauna. He concluded that the *Parabolinella* fauna was younger than the *Kainella* fauna and therefore was in the upper part of the Lower Tremadocian.

Harrington & Leanza (1943) found *Parabolina argentina*, *Jujuyaspis keideli* and *Dictyonima flabelliforme* associated on the same rock slab in material collected at Salitre, Bolivia. Inasmuch as *D. flabelliforme* is an index form of the lower Tremadocian in England and Sweden, this seemed to prove the age of the fauna. Genera of the *Kainella* fauna were collected from another horizon, which was interpreted to underlie the *P. argentina* fauna.

Recent work by Harrington & Leanza (1957), based on uninterrupted sequences of trilobite-bearing Lower Ordovician beds, has shown that beds containing *Parabolina argentina* characterize lowermost Tremadocian. They have termed the trilobite assemblage found in lower Tremadocian rocks the "*Kainella* fauna" and subdivided it into the fauna of the lowermost Tremadocian zone designated as the *Parabolina argentina* zone and the overlying *Kainella meridionalis* zone.

The presence of *Parabolina argentina* in Venezuela forms one more link in the chain of developing evidence concerning the distribution of the Atlantic province olenid fauna in Upper Cambrian and early Ordovician time. Wilson (1954, 1957) has summarized some of the data concerning the existence of a seaway extending from Scandinavia and England to Newfoundland and Cape Breton, then along the margin of the North American continent to the Marathon region of Texas and into South America. Harrington & Leanza (1957, p. 23–25) have discussed the biological affinities of the fauna of the lowermost Tremadocian zone with forms from other areas of the world.

The geographic distribution of some of the genera and species associated with *Parabolina argentina* provides additional information concerning the existence of a seaway connecting the continents of Europe with North and South America during Upper Cambrian and Tremadocian time.

The *P. argentina* zone fauna of Argentina and Bolivia is relatively large, and includes such correlatable forms as *Dictyonema flabelliforme*, *Geragnostus* (six species), *Jujuyaspis keideli* and *Plicatolina*.

Dictyonema flabelliforme has been found in west Texas, but at a higher stratigraphic position associated with a fauna of Skiddavian age (Wilson, 1954). In eastern New York, *D. flabelliforme* occurs in the Schaghticoke shale of lowermost Ordovician (?) age, and it marks the base of the Tremadocian rocks of Europe. *Jujuyaspis keideli* has been reported from the base of the Dictyonema shales (lowermost Tremadocian) in Norway (Henningsmoen, 1956).

Geragnostus has been reported from the Upper Cambrian Dagger Flat formation in the Marathon uplift region of Texas (Wilson, 1954); from lower Tremadocian beds in northwestern Vermont, where it is associated with a species of *Plicatolina* very similar to the South American form (Shaw, 1951, 1955); and from the Upper Cambrian *Peltura* zone of Sweden (Westergärd, 1947).

Parabolina argentina is an abundant form in the lowermost Tremadocian of Argentina and Bolivia. This is the first report of its occurrence in Venezuela. Richardson (1948) has reported *P. argentina* from the lower Tremadocian of Newfoundland; and this species seems very closely related to *Parabolina dawsoni* from the *Peltura* zone of the MacNeil formation (Upper Cambrian) of Cape Breton Island (Hutchinson, 1952) and to *Parabolina longicornis* and *P. megalops* from the *Peltura* zone in Scandinavia.

SYSTEMATIC DESCRIPTION

TRILOBITA

Order POLYMERA Jaeckel, 1909

Superfamily OLENOIDAE Hupé, 1952

Family OLENIDAE Burmeister, 1843

Genus PARABOLINA Salter, 1849

PARABOLINA ARGENTINA (Kayser), 1876

Pl. 80, figs. 1–5

Olenus argentinus Kayser, 1876, p. 6, pl. 1, fig. 3.
Parabolinella andina Hoek, 1912, Neues Jahrb. für Min. Band XXXIV, p. 219, pl. VII, figs. 7–9.

Parabolina andina (Hoek) Kobayashi, 1937, p. 477, pl. IV, figs. 10–12; pl. VIII, fig. 3.
Parabolina argentina (Kayser) Harrington & Leanza, 1957, p. 81, figs. 25, 1–5; 26, 1–17. (Complete synonymy).

The specimens from the Mireles formation of Venezuela can all readily be assigned to this species. Although details of the cranidium have been all but obliterated by the distortion of the sediments in which they occur, other diagnostic features are well preserved. The specimens have the characteristic features of *P. argentina*, namely: the macropleural spines of the eighth thoracic segment, the strong mesial spine on the last (12th) thoracic segment, the rounded, serrated pydigium of 3–4 segments and the broad cephalon with elongate genal spines.

Occurrence.—Mireles formation, Cerro Mireles, El Baul, Venezuela.

Age.—Lower Tremacodian.

Figured Specimens.—All specimens illustrated are so labeled and are in the collection of the Direccion de Geologia, Ministerio de Minas e Hydrocarburos, Republica de Venezuela, Caracas.

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ARENACEOUS FORAMINIFERA FROM THE MIDDLE DEVONIAN LIMESTONES OF OHIO

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ABSTRACT—Insoluble residues from the Columbus limestone yielded 33 species belonging to 10 genera of arenaceous foraminifera, which are described here; among them are 2 new genera, *Weikkoella* and *Fairliella*, and 19 new species. A discussion of morphologic features of these foraminifera includes a comparative evaluation of their taxonomic use in this study. The associated fauna is summarized, and implications of the ecology are suggested, namely, a warm, somewhat shallow marine environment.

INTRODUCTION

THIRTY-THREE species of arenaceous foraminifera, including 19 new species and 2 new genera, were recovered from insoluble residues from selected outcrop sections of the Columbus limestone in Ohio. The study of the insoluble residues is reported by Summerson et al. (1957). The residues were prepared by digestion of 15–25 gram samples in dilute hydrochloric acid. Since there was no special handling to preserve microfossils, some specimens were undoubtedly lost or destroyed by vigorous acid reaction and washing.

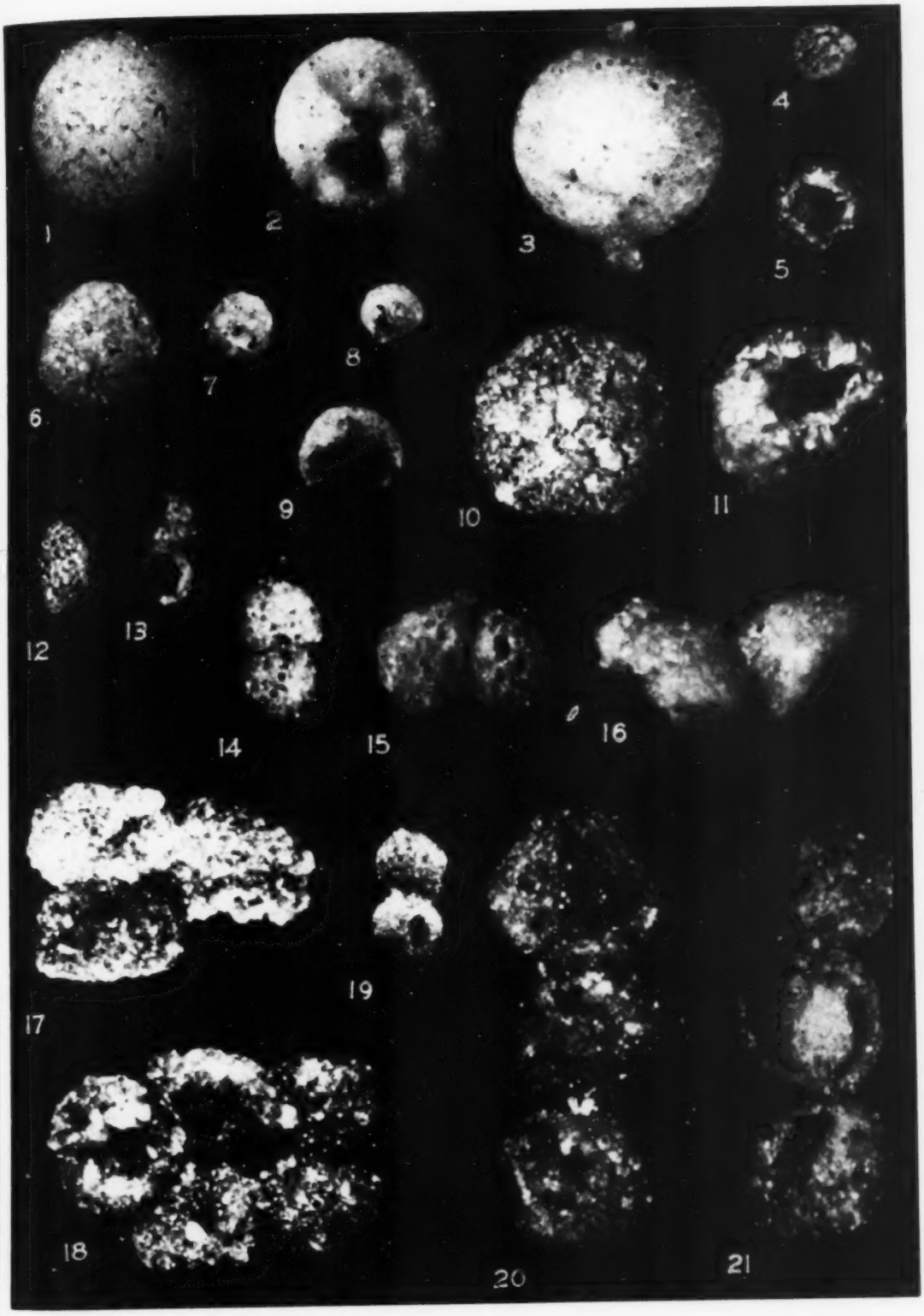
Samples were taken mainly from quarry sections, in scattered localities from Franklin County north to Lake Erie. Arenaceous foraminifera were found in all sections, but the greatest number of those recovered are from the central Ohio area, where repeated sampling was done for use in comparison of methods of making residues and for training of students.

The stratigraphy of the Columbus limestone has been studied and reported by several people; the most complete description is by Stauffer (1909), the most recent faunal analysis by Stewart (1955). Just published by Stauffer (1957) is a summary of regional correlations. In central Ohio two members of the Columbus are usually recognized, the lower being the Bellepoint and the upper the Delhi. The Bellepoint is a brown, medium-grained, thick-bedded,

EXPLANATION OF PLATE 81

All specimens approximately ×40

FIGS. *1,2*—*Weikkoella spherica*, n. sp., *1*, external view of holotype. *2*, broken specimen showing characteristic labryrinthic chamber.
3—*Weikkoella binodosa*, n. sp., holotype.
4—*Psammosphaera delicatula* Stewart & Lampe.
5—*Psammosphaera devonica* Stewart & Lampe, broken specimen, showing thickness of wall and interior.
6—*Psammosphaera discoidea* Stewart & Lampe, top view of specimen.
7—*Psammosphaera exerpta* Dunn.
8—*Psammosphaera gracilis* Ireland, slightly broken specimen.
9—*Psammosphaera rotunda* Stewart & Lampe, broken specimen showing very thin wall.
10,11—*Psammosphaera aspera*, n. sp., *10*, holotype. *11*, broken paratype showing thickness of wall and interior of test.
12—*Psammosphaera elongata*, n. sp., holotype.
13—*Sorosphaera bicella?* Dunn, broken specimen.
14—*Sorosphaera bicelloidea* Stewart & Lampe.
15—*Sorosphaera columbiense* Stewart & Lampe.
16—*Sorosphaeroidea polygonia* Stewart & Lampe.
17—*Sorosphaeroidea trichora*, n. sp., top view of holotype.
18—*Sorosphaeroidea pentachora*, n. sp., top view of holotype.
19—*Psammosphax? bipartita* Ireland.
20,21—*Psammosphax hormiscoides*, n. sp., *20*, top view of holotype. *21*, bottom view of holotype.



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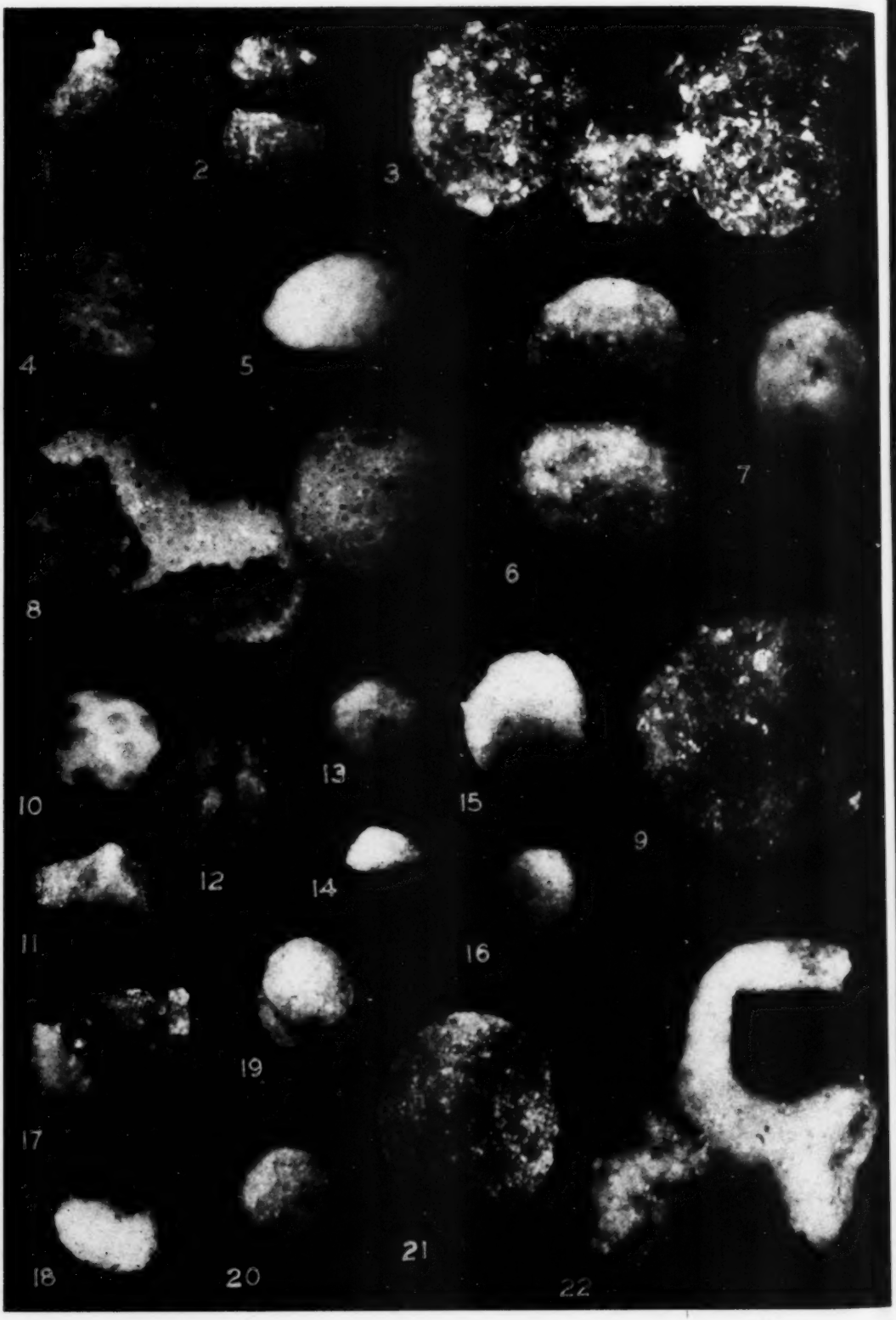
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somewhat fossiliferous dolomite and dolomitic limestone about 35 feet thick. Because there is little economic interest in it, it is rarely exposed in quarries. It is not recognized to the north, where it has been interpreted as pinching out below the overlying Delhi. The Delhi member is a widely-quarried gray, medium-grained, medium-bedded, very fossiliferous limestone about 65 feet thick. Because of the more numerous and thicker exposures of the Delhi, most of the samples from which specimens were obtained came from this member. Sampling inequalities in both quantity and stratigraphic range prevent any generalization of distribution of the various species.

Photographs were made through a monocular microscope with a "pinhole" diaphragm, 0.075 inch in diameter, fitted above the objective. To allow good delineation of surface texture resulting from variations in grain sizes and in amount of cement, the specimens were not coated. The high illumination required by the "pinhole" diaphragm prevented well-developed shadows; therefore outline sketches are included to show better those elements of shape not otherwise easily recognizable.

PREVIOUS WORK

Six papers have been published describing foraminifera from the Devonian of North America. The majority of those described are arenaceous. Thomas (1931) first reported *Endothyra gallowayi*, from the Lime Creek (Hackberry) of Iowa; Moreman (1933) described one species from the Haragan of Oklahoma; Ireland (1939) described eleven species (six new) also from the Haragan; Cushman & Stainbrook (1943) described nine species (one new genus and one new species) from the Independence shale of Iowa; and, most recently, Stewart & Lampe (1947) described thirteen new species, including two new genera, from the Middle Devonian "bone beds" (Columbus and Delaware formations) of Ohio. Additional references to the occurrence of arenaceous foraminifera, without identification or description, are found in Fenton & Fenton (1924, p. VII), who reported them from the Hackberry of north-central Iowa; and Croneis, Dunn & Hunter (1932, p. 138), who mentioned their occurrence in abundance in the Lower Devonian of southeastern Missouri.

Undoubtedly a much greater record of

EXPLANATION OF PLATE 82

All specimens approximately ×40

FIG. *1*—*Proteonina helena*, n. sp., holotype, showing color variation from white at top to light brown at bottom.
2—*Webbinella bipartita* Ireland, top view of specimen, showing closely joined chambers.
3—*Webbinella disparicella*, n. sp., top view of holotype, showing unequal chambers of low convexity.
4,5—*Webbinelloidea hemispherica* Stewart & Lampe, *4*, top view. *5*, side view, showing lack of peripheral flange.
6—*Webbinelloidea similis* Stewart & Lampe, top view of specimen.
7—*Webbinelloidea sola* Stewart & Lampe, top view of specimen, showing surface more finely textured than that of *W. hemispherica*.
8—*Webbinelloidea trilocularis* Stewart & Lampe, top view of broken specimen.
9—*Webbinelloidea rugosa* n. sp., top view of holotype.
10,11—*Webbinelloidea multicarinata*, n. sp., *10*, top view of holotype. *11*, side view of holotype.
12—*Webbinelloidea nodosa*, n. sp., top view of holotype.
13,14—*Webbinelloidea polyhedra*, n. sp., *13*, top view of holotype. *14*, side view of holotype.
15,16—*Fairliella carmani*, n. sp., *15*, top view of holotype. *16*, top view of smaller specimen included in the same species.
17,18—*Fairliella clitellata*, n. sp., *17*, top view of holotype. *18*, top view of smaller form included in the same species.
19—*Fairliella dicantha*, n. sp., perspective view of holotype.
20—*Fairliella discoidea*, n. sp., top view of holotype.
21—*Fairliella lameyi*, n. sp., top view of holotype, showing fine grains and dark coloring.
22—*Schizammina sp.*, side view of incomplete specimen.

Devonian foraminifera exists, possibly as extensive as that known from the Silurian. Arenaceous foraminifera have rarely been a direct objective of search. Usually, as here, their recovery has been a by-product of insoluble residue studies, and frequently the techniques used have not been designed primarily for the recovery of microfossils. Better recovery is possible by careful handling and the use of very dilute acid. Such acids as formic and acetic are proving of special value in the freeing of microfossils. Continued study of these fossils should prove rewarding, for the Devonian faunas are distinctly different from the Silurian, and their potential value for stratigraphic use in smaller-than-systemic units is a promising and yet-untested field.

MORPHOLOGY AND CLASSIFICATION

Morphology is the only immediate guide in the determination of genera and species of the Paleozoic arenaceous foraminifera. Evaluation of the various features used in identification seems often to have been inconsistent, and assignment of some species to genera has either ignored the generic description or broadened it without formally stating the fact. Thus many generic descriptions have become overly broad or too brief, and should be restudied.

The morphologic features of the test used for specific and generic description in this paper follow generally those outlined by Galloway in his *Manual of Foraminifera* (1933). The features are discussed here in order of their importance in defining a species. When several species have certain of their important features in common and are distinct from other forms, they are set apart as a genus, with the common elements of the morphology used as the defining characteristics and the remaining features described within the limits of their variation.

Since arenaceous foraminifera represent a morphologic group rather than a taxonomic division, the tests include representatives of several families. Family identification was made according to the keys of Cushman (1950). Within the families, the following features were found most useful in generic and specific determination: (1) attachment, if any; (2) chambers—character, number and arrangement; (3) shape—plan and side view, including irregularities or variations; (4) wall structure—grain size, kind and sorting; type and amount of cement; surface, and thickness; (5) apertures, if any—shape, number and position; (6) color; and (7) dimensions. Ornamentation in the specimens studied is of little taxonomic value in itself; it usually reflects cementation or grain size, shape, and sorting.

The comparative taxonomic value of these features varies somewhat from one form to another. For example, although many specific descriptions include both free and attached forms, in others attachment is critical. It is sometimes rather difficult to identify. Uusually a face of attachment is a flat area of especially fine grains, forming a wall which is thinner, smoother, and more nearly transparent than others in the test.

The number and arrangement of chambers are of particular importance in placing the test in its proper family. Other features of the chamber may be important in generic and specific designation. In single-chambered tests—*e.g.*, *Psammosphaera*—the chamber outline is important; in multiple-chambered tests, the number and arrangement of chambers as well as the outline are useful. The chamber interior of most forms is a simple hollow reflecting the exterior of the test; however, in the newly-described genus *Weikkoella*, the interior of the chamber is an irregular labyrinth, so distinctive as to set the genus apart.

The shape of the test is often the critical feature in specific identification. It is necessary, however, to rely somewhat on personal judgment—for example, in attached species, in which a diversity of shapes results from the vagaries of orientation of the surface or cranny to which the test is attached. If irregularities in shape are determined by the surface or face of attachment, and especially if duplication is infrequent, correspondingly less weight for taxonomic use can be given to the variation of shape. A shape that is consistently present in a number of specimens is worthy of greater consideration as a specific characteristic.

Wall structure varies with such elements as grain composition, shape, size and sorting. In the specimens described here, the grains are quartz, mostly clear, angular to sub-angular, ranging from 0.01 mm. to

0.1+ mm. in diameter; smaller grains are probably present in the cement, but have not been recognized. Since the wall is usually a single-grain layer, its thickness is directly related to the size of the grain. Forms having a coarse and angular grain ordinarily have a rough surface; occasionally however, a species has fitted coarse grains so well as to give a very smooth surface. Some forms seem deliberately to have placed large grains to project above the general surface, giving a suggestion of a spinose surface. As it varies in amount and kind, cement also strongly influences wall structure. In the specimens studied, chitinous cement prevails, with some siliceous and "ferruginous" or a combination of these possibly present. A large quantity of cement apparently makes a flexible wall (flexibility is suggested by the collapsed rather than fragmented appearance of some of the crushed specimens) and/or a very smooth outer surface; a small quantity makes a more rigid wall and/or a grainy surface. Some specimens have so much cement that it obscures the identity of the grains; others have so little that it is hardly recognizable. The composition of the cement is largely responsible for the color of the specimens.

In many foraminifera the aperture is, taxonomically, one of the most important features; however, in the majority of the Devonian forms described here, none has been identified. Instead, a series of irregular interstitial openings, so fine as to be difficult if not impossible to recognize, probably served for the projection of the pseudopodia. An exception is the genus *Proteonina:* it has a well-defined aperture, the character and position of which are valuable in its classification.

Color is of significance in identification probably only as it is related to other such features as grains or cement. Colors of specimens studied here vary from milky white to clear or yellowish or brown. The quartz grains themselves are usually clear, but some are milky or opaque white. As was mentioned above, color is greatly influenced by cement. It may also be the result of a petroleum or iron stain.

In most species studied, dimensions vary less than ten percent; they rarely vary as much as twenty percent. In a genus such as *Psammosphaera*, dimensions are one of the critical features in specific description. However, in some species, notably *Fairliella carmani* and *F. clitellata*, although all other characteristics are identical, the individuals occur in two distinct sizes, one approximately one-third to one-half smaller than the other. These specimens were first thought to represent two species, but the very striking resemblance between them suggests that they may be examples of dimorphism, a characteristic of many foraminifera.

ECOLOGY AND ASSOCIATED FORMS

Ecological references to arenaceous foraminifera are few and usually very general. Most commonly the descriptions of living representatives of genera which occur in the Columbus read "marine, benthonic, cold, deep water." In the description of certain living representatives of *Webbinella*, Cushman (1910, p. 51) has recorded comparatively shallow depths, 50–100 fathoms; however, he describes (1955, p. 75) the family Saccamminidae, which includes such genera as *Psammosphaera*, *Sorosphaera*, and *Webbinella*, as cool, deep water, marine forms. Galloway (1933, p. 55) describes the family Astrorhizidae as "marine, benthonic, mostly in deep, cold water," with a few examples known from shallow water, temperate or warm; he also lists *Psammosphaera*, *Sorosphaera* and *Webbinella* as occurring in deep, cold water, 1000 fathoms or deeper.

Associated with arenaceous foraminifera in the residues of the Columbus limestone are scolecodonts (to be described in a later report); sponge spicules; fish plates; unidentified spore-like bodies; and silicified fragments of brachiopods, crinoid plates and columnals, and bryozoa. These are part of an extensive fauna (see Stauffer, 1909; Stewart, 1955) which includes corals, stromatoporoids, crinoids, blastoids, bryozoa, brachiopods, pelecypods, gastropods, cephalopods, pteropods, trilobites and fish remains. In addition to this fauna, such features as "bone beds," interpreted by Wells (1944, p. 297) as forming above wave base, and biostromal layers of corals and stromatoporoids suggest an environment other than that reported for living

representatives of the arenaceous foraminifera. The fauna and the associated sedimentary features found in the Columbus are interpreted by Wells (1947, p. 119) as representing "warm, clear, well illuminated, quiet seawater of normal salinity."

It is possible that the apparent ecologic variations between the Devonian arenaceous foraminifera and the modern forms may be explained by one or a combination of the following: (1) too broad taxonomic designations and a need for separation of modern arenaceous foraminifera from fossil forms; (2) a change of environmental conditions of arenaceous foraminifera since the Devonian; (3) a greater tolerance in living foraminifera than present knowledge has been able to recognize. Galloway, in his discussion of the development of arenaceous foraminifera, suggests that their present environment is one of specialization, not a primitive state. If this interpretation is correct, it would help to explain the difference between the habitats of the living and those of the Devonian forms as resulting from a gradual specialization through geologic time.

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DESCRIPTION OF LOCALITIES

1. Marble Cliff Quarries Co. (Main or North Quarry) on Trabue Road one-quarter mile west of Scioto River, Norwich Township, Franklin County (West Columbus quadrangle).
2. Dublin Quarry (abandoned), just south of Dublin, on west side of Scioto River, Washington Township, Franklin County (Dublin quadrangle).
3. Union Quarry (Clymer Materials Co.), 2 miles east of Watkins, Mill Creek Township, Union County (Dublin quadrangle).
4. Klondike Quarry (Scioto Lime and Stone Co., Inc.), 2 miles north of Bellepoint on east side of Scioto River, Scioto Township, Delaware County (Delaware quadrangle).
5. John Evans Quarry (abandoned), in northwest part of Marion, Marion County (Marion quadrangle).
6. Spore Quarry of Broken Sword Stone Co., on Broken Sword Creek about 6 miles northwest of Bucyrus, near Spore, Holmes Township, Crawford County (Sycamore quadrangle).
7. Bellevue Stone Co. Quarry, on north side of U. S. Highway 20, just west of Bellevue, York Township, Sandusky County (Bellevue quadrangle).
8. Wagner Quarries Co., across road from south corner of Soldiers' Home in southeastern Sandusky, Erie County (Sandusky quadrangle).

DESCRIPTION OF SPECIES

Family ASTRORHIZIDAE Brady, 1881

Genus WEIKKOELLA Summerson, n. gen.

Type species.—*Weikkoella spherica*, n. sp.

Test free, spherical, with smooth outline, consisting of an irregular labyrinthic chamber, which may or may not be everywhere interconnected, with intervening space built solid; surface finely pitted, of well-cemented and well-sorted quartz grains (silt size); labyrinthic chamber formed of irregularly branching channels with smooth walls, varying in diameter and distributed throughout test without a definite pattern; aperture not apparent; channels closed by a continuous outer wall; color white to brown.

Remarks.—*Weikkoella* is placed in the family Astrorhizidae because its internal structure suggests a close relationship to *Crithionina*. It is distinguished from *Crithionina* on the basis of the labyrinthic chamber in an otherwise solid test and the absence of the central cavity.

WEIKKOELLA SPHAERICA Summerson, n. sp.

Pl. 81, figs. 1,2; text-fig. 1a

Test free, spherical, consisting of an irregularly branching labyrinthic chamber with intervening spaces built solid. Outline smooth; surface finely pitted, of well-cemented and well-sorted subangular grains 0.02 mm. or less in diameter. Chamber walls smooth; passages vary abruptly in diameter, and their distribution and arrangement show no apparent pattern. Color variation from white to brown is probably caused by varying amounts of petroliferous residue present in the matrix rocks.

Dimension.—Diameter of holotype, 0.72 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—Some specimens are somewhat

ellipsoidal, probably because of crushing. Some have openings, up to 0.08 mm. in diameter, that penetrate the surface, but these suggest damage by acid treatment rather than natural structures.

Holotype.—No. 22270, Geological Museum, Ohio State University.

WEIKKOELLA BINODOSA Summerson, n. sp.
Pl. 81, fig. 3; text-fig. 1b

Test free, spherical, with smooth outline, slightly pitted surface; consists of well-cemented and well-sorted subangular grains 0.02 mm. in diameter. Outstanding feature of species is presence of two polar necklike protuberances 0.09 mm. high. Surface has occasional openings suggesting loss of grains by acid damage rather than design. Interior solid except for a labyrinthic system of irregular smooth-surfaced branching passages of varying diameter and without pattern in their distribution or arrangement; they do not connect to the surface and no aperture is apparent. Color varies from white to brown.

Dimension.—Diameter of holotype, 0.75 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—Some partially broken specimens suggest that some of the passages may be independent chambers. The species is less common than *W. spherica;* some specimens are similarly crushed to somewhat ellipsoidal shape.

Holotype.—No. 22272, Geological Museum, Ohio State University.

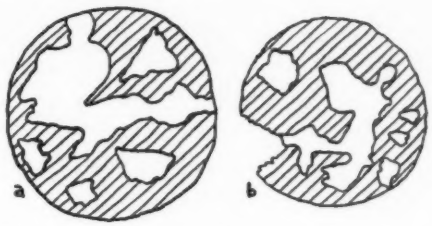
Family SACCAMMINIDAE Eimer & Fichert, 1899

Genus PSAMMOSPHAERA Schulze, 1875

PSAMMOSPHAERA DELICATULA Stewart & Lampe
Pl. 81, fig. 4

Psammosphaera delicatula Stewart & Lampe, 1947, p. 532, pl. 78, figs. 1a,b.

Test free, small, consisting of a single somewhat ellipsoidal chamber; thin, delicate wall of single-layer thickness of well-cemented subangular, clear quartz grains 0.025 mm. or less in diameter; surface somewhat rough with occasional projecting grains; no aperture apparent; color clear; interior surface somewhat irregular, closely



TEXT-FIG. *1*—Cross-section sketches showing chamber configuration (unshaded portion); *a*, *Weikkoella spherica*, n. sp., paratype; *b*, *W. binodosa*, n. sp. ×40.

reflecting slight outer shape irregularities.

Dimension.—Long diameter 0.25 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—Figured specimen No. 22273, Geological Museum, Ohio State University.

PSAMMOSPHAERA DEVONICA Stewart & Lampe
Pl. 81, fig. 5

Psammosphaera devonica Stewart & Lampe, 1947, p. 533, pl. 78, fig. 2.

Test free, somewhat ellipsoidal, small, with single, hollow chamber; consists of grains of well-cemented subangular clear quartz about 0.04 mm. or less in diameter. Thickness of wall is approximately two layers of grains, and a small part of interior is filled with very clear quartz grains, probably of secondary origin. Outer surface is somewhat rough, with occasional projecting grains. No aperture apparent. Color slightly yellowish.

Dimension.—Diameter 0.37 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 5.

Remarks.—Stewart and Lampe separate this species from *delicatula* on larger size, more nearly rounded shape. The specimen here described also has thicker walls. Figured specimen No. 22274, Geological Museum, Ohio State University.

PSAMMOSPHAERA DISCOIDEA Stewart & Lampe
Pl. 81, fig. 6

Psammosphaera discoidea Stewart & Lampe, 1947, p. 533, pl. 78, figs. 3a,b.

Test free, somewhat flattened sphere, single chamber; delicate wall of one-grain

thickness; clear quartz grains, poorly sorted, from 0.02–0.045 mm. in diameter, some rather large for size of specimens, rather loosely cemented; surface fairly smooth with an occasional grain projecting above the general level; interior smooth; no aperture identified; color light yellowish.

Dimensions.—Long diameter, 0.47 mm., short diameter 0.27 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—Characterized by distinctly flattened or ellipsoidal shape. Figured specimen No. 22275, Geological Museum, Ohio State University.

PSAMMOSPHAERA EXERPTA Dunn
Pl. 81, fig. 7

Psammosphaera exerpta Dunn, 1942, Jour. Paleontology, v. 16, p. 323, pl. 42, figs. 7,8.

Test free, spherical, typically small, with single hollow chamber; composed of comparatively large subangular clear quartz grains, well cemented, approximately 0.036 mm. in diameter, in a matrix of very fine angular quartz grains about 0.01 mm. in diameter, giving a mosaic effect. Surface somewhat rough; wall of single-grain thickness; no aperture apparent; color clear.

Dimension.—Diameter 0.27 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—*P. exerpta* is distinguished from *P. delicatula* by the much coarser grains. Figured specimen No. 22276, Geological Museum, Ohio State University.

PSAMMOSPHAERA GRACILIS Ireland
Pl. 81, fig. 8

Psammosphaera gracilis Ireland, 1939, p. 194, figs. A-10,11.

Test free, nearly spherical, composed of well-cemented, uniformly very fine subangular clear quartz grains approximately 0.01 mm. or less in diameter; wall delicate, of one-grain thickness; interior smooth; exterior slightly rough under higher magnifications; no aperture identified; color clear to light yellowish.

Dimension.—Diameter 0.02 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—The well-sorted, very fine grains distinguish *P. gracilis* from *P. exerpta* and *P. delicatula*. Descriptions of *P. minuta* Dunn and *P. gracilis* Ireland differ very little, and there may be some question as to whether they are different species. The specimen figured is broken, showing part of the interior. Figured specimen No. 22277, Geological Museum, Ohio State University.

PSAMMOSPHAERA ROTUNDA Stewart & Lampe
Pl. 81, fig. 9

Psammosphaera rotunda Stewart & Lampe, 1947, p. 533, pl. 78, fig. 4.

Test free, spherical, consisting of a single chamber of well-cemented, well-sorted, fine quartz grains approximately 0.015 mm. or less in diameter; wall thin, delicate, of single-grain thickness, well cemented, smooth on both interior and exterior; no aperture identified; grains clear, slightly iron stained.

Dimension.—Diameter at least 0.51 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—Test is unusually large, and regular in shape, with the wall very thin in proportion to overall size. Grains are especially well sorted for a species of this genus. Figured specimen No. 22278, Geological Museum, Ohio State University.

PSAMMOSPHAERA ASPERA Summerson, n. sp.
Pl. 81, figs. 10,11

Test free, nearly spherical, unusually large, composed of poorly sorted angular grains up to 0.1+ mm. in diameter; wall of single-grain thickness, surface rough, grains well cemented and tightly fitted. Interior a single chamber with rough surface; broken paratype (Pl. 81, fig. 11) partially filled with quartz grains which are probably secondary. No aperture identified. Color brown, with quartz grains rather clear, and cement colored.

Dimension.—Diameter 0.76 mm.

Ocurrence.—Columbus limestone, Bellepoint member. Locality 3.

Remarks.—This species differs from others of the genus in its unusually large size and large grains.

Holotype.—No. 22279, paratype No. 22280, Geological Museum, Ohio State University.

PSAMMOSPHAERA ELONGATA Summerson, n. sp.
Pl. 81, fig. 12

Test free, elongate spheroid or cylindrical shape, single chamber; wall thin, well cemented, of fairly well sorted subangular clear quartz grains 0.03 ± mm. in diameter; surface rough; no aperture identified; color clear.

Dimensions.—Long diameter 0.37 mm., short 0.2 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—The species is characterized by its long, somewhat cylindrical shape.

Holotype.—No. 22281, Geological Museum, Ohio State University.

Genus SOROSPHAERA, Brady, 1879
SOROSPHAERA BICELLA? Dunn
Pl. 81, fig. 13

Sorosphaera bicella Dunn, 1942, Jour. Paleontology, v. 16, p. 325, pl. 42, figs. 17,18.

Test free, consisting of two nearly spherical chambers loosely connected; wall thin, of moderately sorted, thinly cemented subangular grains 0.02 mm. and less in diameter; surface slightly rough; no aperture identified; color clear.

Dimensions.—Total length 0.44 mm., chamber diameter 0.24 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—The identification is uncertain because the test is broken. Figured specimen No. 22282, Geological Museum, Ohio State University.

SOROPHAERA BICELLOIDEA Stewart & Lampe
Pl. 81, fig. 14

Sorosphaera bicelloidea Stewart & Lampe, 1947, p. 534, pl. 78, fig. 6.

Test attached, consisting of two slightly biconvex chambers strongly joined but not interconnected, one chamber slightly larger; wall thick, of poorly sorted, well-cemented subangular clear quartz grains 0.03 mm. or less in diameter; surface smooth, lower surface smoother and of finer grains than upper; no aperture identified; color gray-white.

Dimensions.—Total length 0.58 mm., diameter of single chamber 0.30 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—Figured specimen No. 22283, Geological Museum, Ohio State University.

SOROSPHAERA COLUMBIENSE Stewart & Lampe
Pl. 81, fig. 15

Sorosphaera columbiense Stewart & Lampe, 1947, p. 533, pl. 78, figs. 5a,b,c.

Test free, consisting of two loosely joined, irregularly globular to flask-shaped chambers; wall thin, delicate, lightly cemented, with somewhat rough surface, composed of poorly sorted, subangular, clear quartz grains up to 0.09 mm. in diameter; no aperture identified; color white.

Dimensions.—Total length 0.68 mm., long diameter of single chamber 0.49 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—Figured specimen No. 22284, Geological Museum, Ohio State University.

Genus SOROSPHAEROIDEA Stewart & Lampe, 1947
SOROSPHAEROIDEA POLYGONIA Stewart & Lampe
Pl. 81, fig. 16

Sorosphaeroidea polygonia Stewart & Lampe, 1947, p. 534, pl. 78, figs. 7a,b,c.

Test attached, composed of two chambers with evidence of a third, well joined but not interconnected. Shape irregular; upper surface curved and lower surface of several flat polygonal faces in various orientations. Strong wall of well-cemented subangular quartz grains up to 0.035 mm. in diameter; fairly smooth outer surface; polygonal faces (probably attachment surfaces) of finer grains. No aperture identified. Color white.

Dimension.—Chamber length 0.51 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—There is some question as to the identity of this species because the holotype is broken and it is therefore difficult to judge the influence of attachment surfaces on the shape. Figured specimen No. 22285, Geological Museum, Ohio State University.

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SOROSPHAEROIDEA TRICHORA Summerson, n. sp.
Pl. 81, fig. 17

Test attached, composed of three separate but firmly joined chambers of planoconvex shape; surface of attachment sharply curved; walls somewhat thick, of well-cemented angular quartz grains up to 0.16 mm. in diameter, poorly sorted and forming a very rough surface; chambers collapsed, suggesting somewhat flexible walls or a large amount of cement; basal wall thinner, smoother and finer grained than others; no aperture apparent; color light brown.

Dimensions.—Longest dimension 1.03 mm.; diameter of single chamber 0.51 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 6.

Remarks.—*Sorosphaeroidea trichora* differs from *S. polygonia* in both wall structure and arrangement of chambers. *S. trichora* is made up of larger and more poorly sorted grains with a resultant rougher, heavier wall. Although the holotype of *S. polygonia* is broken and the arrangement of chambers is uncertain, they appear to have been along a rather straight line, whereas in the several specimens of *S. trichora* they form a right angle.

Holotype.—No. 22286, Geological Museum, Ohio State University.

SOROSPHAEROIDEA PENTACHORA Summerson, n. sp.
Pl. 81, fig. 18

Test attached, composed of five hemispherical chambers strongly but not tightly joined, without interior connection, moderately convex and with base of nearly circular outline; wall of well-cemented subangular quartz grains up to 0.05 mm. in diameter; large amount of cement gives a suggestion of flexibility, and chambers are slightly collapsed; surface somewhat rough; attached surface a strong U curve and only slightly smoother than upper surface; no aperture apparent; color light brown.

Dimensions.—Total length 1.26 mm., single chamber diameter 0.51 mm., chamber height 0.27 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 6.

Holotype.—No. 22287, Geological Museum, Ohio State University.

Remarks.—This species is very similar to *S. trichora* (n. sp.) but is differentiated on the basis of the greater number of chambers.

Genus PSAMMOSPHAX Rumbler, 1931
PSAMMOSPHAX? BIPARTITA Ireland
Pl. 81, fig. 19

Psammosphax bipartita Ireland, 1939, p. 194, figs. A-24,25.

Test attached, composed of two lightly joined hemispherical chambers of moderate convexity and with flattened basal surface; wall thin, smooth inside and out, of well-cemented fine quartz grains approximately 0.02 mm. and less in diameter; no aperture identified; color light yellowish brown.

Dimensions.—Long dimension 0.41 mm., long diameter of individual chamber 0.24 mm.

Occurrence.—Columbus limestone. Locality 8.

Remarks.—This specimen is larger and has a greater separation of chambers than the species described by Ireland. Figured specimen No. 22288, Geological Museum, Ohio State University.

PSAMMOSPHAX HORMISCOIDES Summerson, n. sp.
Pl. 81, figs. 20,21

Test attached, consisting of three loosely attached chambers with exterior suggesting a possible fourth in a line; chambers of somewhat rectangular outline, hemispheric, of moderate convexity without inner connection; upper surface partially collapsed; surface of attachment finer grained, lighter colored, slightly depressed as though from shrinkage; wall of well-cemented subangular quartz grains 0.06 mm. and less in diameter; moderately rough surface; no aperture identified; color tan.

Dimensions.—Total length 1.72 mm., chamber diameter 0.55 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 5.

Holotype.—No. 22289, Geological Museum, Ohio State University.

Genus PROTEONINA Williamson, 1858
PROTEONINA HELENA Summerson, n. sp.
Pl. 82, fig. 1

Test free, composed of one ovate, flask-

shaped chamber with a gently tapering neck containing a small circular aperture about 0.02 mm. in diameter; outline generally smooth but interrupted by several stubby protuberances without apertures; wall of well-sorted, well-cemented very fine grains giving a fine granular surface; color light brown.

Dimensions.—Length 0.44 mm., width 0.34 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—Generally resembles *P. ovata* Dunn but differs in the presence of the protuberances.

Holotype.—No. 22290, Geological Museum, Ohio State University.

Genus WEBBINELLA Rhumbler, 1903
WEBBINELLA BIPARTITA Ireland
Pl. 82, fig. 2

Webbinella bipartita Ireland, 1939, p. 198, figs. B-14,15.

Test attached, consisting of two subequal flattened hemispherical chambers, strongly joined but not interconnecting, with moderate flange at outer edge. Basal view suggests that one chamber was formed first and the second joined to it. Wall is of well-sorted, very fine quartz grains 0.028 mm. and less in diameter, well cemented, with cement forming a smooth outer coat; basal wall of finer grains and with less cement. No aperture identified. Color brown, except base, which is light yellow.

Dimensions.—Total length 0.61 mm., individual chamber diameter 0.40 mm., chamber height 0.13 mm.

Occurrence.—Columbus? limestone. Locality 8.

Remarks.—Specimens differ from *Sorosphaera bicelloidea* in wall structure, amount of cement and grain size. Unfortunately I was unable to see Ireland's types for comparison. Figured specimen is No. 22291, Geological Museum, Ohio State University.

WEBBINELLA DISPARICELLA Summerson, n. sp.
Pl. 82, fig. 3; text-fig. 2

Test attached, composed of several hemispherical chambers of low convexity, closely joined but not interconnected, generally circular in outline but varying somewhat in diameter, with flange at least one to two grains in width on outer borders. The type shows three chambers in a row and a broken portion of a fourth at one side. Surface of attachment slightly curved; wall composed of grains 0.04 mm. and less in diameter, subangular, well cemented, with cement forming a general outer cover smoothing the granular surface. Attachment surface is chiefly cement with small numbers of very fine grains; attachment wall is now withdrawn into a convex surface as though from shrinkage. Cement light brown with a suggestion of iron stain. No aperture identified.

TEXT-FIG. 2—*Webbinella disparicella*, n. sp., cross section outline of largest chamber of holotype, showing low convexity and extended flange; basal wall is broken. ×40.

Dimensions.—Total length 1.04 mm., largest chamber 0.49 mm. in diameter.

Occurrence.—Columbus limestone, Delhi member. Locality 6.

Remarks.—Although certain features of the chambers of this species—notably size and arrangement—closely resemble those of *Sorosphaeroidea polygonia*, the well-developed peripheral border is characteristic of the genus *Webbinella*.

Holotype.—No. 22292, Geological Museum, Ohio State University.

Genus WEBBINELLOIDEA Stewart & Lampe, 1947
WEBBINELLOIDEA HEMISPHERICA Stewart & Lampe
Pl. 82, figs. 4,5

Webbinelloidea hemispherica Stewart & Lampe, 1947, p. 535, pl. 79, figs. 1a,b.

Test attached, consisting of a single strongly convex chamber, generally hemispherical in shape but with somewhat oval basal outline. Wall of single grain thickness, composed of poorly sorted subangular quartz grains with maximum diameter approximately 0.06 mm., well cemented, giving a fairly smooth, regular surface; face of attachment of finer grains and therefore thinner. No aperture found; color white.

Dimensions.—Largest diameter 0.63 mm., height 0.28 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—This specimen is a little smaller than the holotype, and its surface is smoother; otherwise, features are identical. Figured specimen No. 22293, Geological Museum, Ohio State University.

WEBBINELLOIDEA SIMILIS Stewart & Lampe
Pl. 82, fig. 6

Webbinelloidea similis Stewart & Lampe, 1947, p. 535, pl. 78, fig. 8.

Test attached, consisting of two hemispherical chambers with flattened surface of attachment; chambers firmly joined, of equal convexity but one slightly smaller; walls medium thick, of well-cemented grains up to 0.04 mm. in diameter; both outer and inner surfaces slightly rough because of coarseness of grains; no aperture identified; color yellow to brown.

Dimensions.—Total length 1.1 mm., diameter of larger chamber 0.62 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 6.

Remarks.—Some specimens have notably finer grains than others. Color varies with cement, some of the browner shades suggesting presence of iron oxide. Figured specimen No. 22294, Geological Museum, Ohio State University.

WEBBINELLOIDEA SOLA Stewart & Lampe
Pl. 82, fig. 7

Webbinelloidea sola Stewart & Lampe, 1947, p. 535, pl. 79, figs. 2a,b,c.

Test attached, consisting of a single hemispherical chamber of somewhat low convexity and slightly oval outline; rather smooth wall of well-sorted, well-cemented quartz grains 0.03 mm. and less in diameter; flattened basal surface of finer grains and smoother; no aperture apparent; color light yellow.

Dimension.—Longest diameter 0.58 mm.

Occurrence.—Columbus limestone, Bellepoint member. Locality 3.

Remarks.—Figured specimen No. 22295, Geological Museum, Ohio State University.

WEBBINELLOIDEA TRILOCULARIS
Stewart & Lampe
Pl. 82, fig. 8

Webbinelloidea trilocularis Stewart & Lampe, 1947, p. 535, pl. 79, figs. 3a,b.

Test attached, composed of three subequal hemispherical chambers of moderate convexity and nearly circular outline, loosely joined along a curving axis; wall thin and smooth, of moderately cemented, subrounded quartz grains 0.06 mm. and less in diameter; attachment surface flat, very thin, of finer grains; no aperture identified; color white.

Dimensions.—Total length 1.53 mm., diameter of largest chamber 0.51 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—Differs from holotype in arrangement of chambers. Figured specimen No. 22296, Geological Museum, Ohio State University.

WEBBINELLOIDEA MULTICARINATA
Summerson, n. sp.
Pl. 82, figs. 10,11

Test attached, composed of a single chamber, roughly hemispherical; upper surface of several irregularly sized and spaced ridges separating somewhat depressed areas of irregular size and distribution; wall of very fine, well-cemented subangular clear quartz grains, thin except at periphery of lower border and at ridges, which seem to have been formed by a doubling or folding of the wall; basal surface of finer grains, forming a smooth, thinner and more nearly transparent wall; no aperture identified; color clear.

Dimensions.—Long diameter 0.51 mm., greatest height 0.24 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 2.

Remarks.—Species is characterized by the unusual configuration which forms the irregular ridges. In the study of *Webbinelloidea multicarinata*, *W. nodosa*, and *W. polyhedra*, consideration was given to the possibility of their representing a new genus: Each possesses a slight peripheral lip, the development of which is less than is typical of *Webbinella* and more than is found in Stewart and Lampe's species of *Webbinelloidea*. However, because of the difficulty of evaluating taxonomically a limited number of specimens, the three species were included in the genus *Webbinelloidea*. Further study may show them to represent a separate genus.

Holotype.—No. 22298, Geological Museum, Ohio State University.

WEBBINELLOIDEA NODOSA
Summerson, n. sp.
Pl. 82, fig. 12

Test attached, composed of a single chamber roughly hemispherical in section and rectangular in plan view; upper surface has two rows of nodes of varying heights, separated by a well-developed sinus; flattened surface of attachment joins upper surface and forms a slight peripheral lip; wall thin, of well-cemented fine subangular clear quartz grains 0.02 mm. and less in diameter; basal surface smoother and of finer grains; no aperture identified; color light yellow.

Dimensions.—Long diameter 0.31 mm., greatest height 0.15 mm.

Occurrence.—Columbus limestone. Locality 7.

Remarks.—This species and *W. multicarinata* have more complex forms than other species of *Webbinelloidea*. However, the single chamber, the slight peripheral lip, and the wall structure of these species seem sufficiently suggestive of *Webbinelloidea* to allow them to be included in that genus rather than to erect a new one.

Holotype.—No. 22301, Geological Museum, Ohio State University.

WEBBINELLOIDEA POLYHEDRA
Summerson, n. sp.
Pl. 82, figs. 3,14

Test attached, consisting of a single somewhat hemispherical chamber, with basal outline roughly circular and upper surface composed of several flat areas or facets suggesting a polyhedron; wall thin, of single grain thickness with slightly rough surface, composed of well-cemented fine (0.03 mm. and less in diameter) subangular clear quartz grains; slight peripheral lip at basal border, but not so well developed as that found in *Webbinella;* basal wall thinner because of finer grains; no aperture identified; color clear.

Dimensions.—Longest diameter 0.38 mm., greatest height 0.14 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.

Remarks.—The diagnostic characteristic of the species is the faceted shape of the upper surface, which on the holotype suggests a pyramid and on other specimens more complex figures.

TEXT-FIG. 3—*Webbinelloidea rugosa*, n. sp., side view of holotype. ×40.

Holotype.—No. 22300, Geological Museum, Ohio State University.

WEBBINELLOIDEA RUGOSA
Summerson, n. sp.
Pl. 82, fig. 9; text-fig. 3

Test attached, composed of single large hemispherical chamber, in these specimens typically collapsed and with a somewhat irregular outline. Junction of the base and upper surfaces somewhat rounded. Wall thick, of well-cemented, poorly sorted subangular quartz grains up to 0.06 mm. in diameter; surface fairly smooth considering size of grains; interior hollow, smooth; basal wall of finer grains, thinner, and smoother. No aperture identified. Color light brown.

Dimension.—Largest diameter 0.96 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 8.

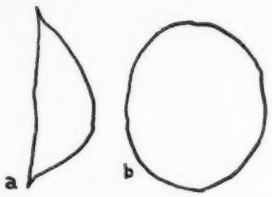
Remarks.—Form is much larger than *W. sola* or *W. hemispherica*. The typically collapsed condition of the specimens may reflect a greater amount of cement, giving a more flexible wall to the test. Coarse grains and poor sorting are most characteristic.

Holotype.—No. 22297, Geological Museum, Ohio State University.

Genus FAIRLIELLA Summerson, n. gen.

Type species.—*Fairliella dicantha* Summerson, n. sp.

Test attached, consisting of a single chamber, the shape of which varies with different species: in some it is nearly hemispherical; in others, less regular. A moderately developed lip or flange, usually of sharp wedge shape, is found at the juncture of the upper surface and the face of attachment; its configuration may be either a circle or an irregular curve; in one species an additional flange further complicates the shape of the test. The wall is composed of fine angular grains tightly placed and well cemented, with a smooth surface typically appearing sheen-like in reflected light. No aperture identified. Color of most species



TEXT-FIG. 4—*Fairliella carmani*, n. sp., outline sketches of holotype; *a*, top view; *b*, cross section. ×40.

light yellow to clear; *F. lameyi* is dark brown.

Remarks.—This genus is placed in the family Saccamminidae because the general structure of the tests is similar to that of *Webbinella*. The persistence of the fine-grained, well-cemented wall composition, the lustrous appearance of the surface, and the wedge-shaped flange in these several species seems to warrant setting them apart as a separate genus. *Fairliella dicantha* is selected as the type species because it best illustrates these characteristic features.

FAIRLIELLA CARMANI Summerson, n. sp.
Pl. 82, figs. 15,16; text-figs. 4a,b

Test attached, composed of a single chamber of somewhat flat plano-convex shape with a wedge-shaped flange at the base; upper surface generally smooth, with a sheen-like appearance; walls thin, well cemented, composed of subangular clear quartz grains up to 0.02 mm. in diameter (most smaller); bottom wall very thin; no aperture apparent; color clear to light yellowish.

Dimensions.—Greatest diameter 0.57 mm., height approximately 0.24 mm.

Occurrence.—Columbus limestone. Locality 1.

Remarks.—This species is placed in *Fairliella* rather than in *Webbinella* because of the distinctive fine-grained wall structure and wedge-shaped flange. In addition to other specimens the size of the holotype, there are several of a smaller size; although a few of the latter have slightly rougher walls, they are generally very similar to the holotype, and the two sizes probably represent a single dimorphic species rather than separate species.

Holotype.—No. 22305, Geological Museum, Ohio State University.

FAIRLIELLA CLITELLATA Summerson, n. sp.
Pl. 82, figs. 17,18; text-figs. 5a,b,c

Test attached, single chambered, saddle shaped, formed of two convex, curved surfaces, the upper slightly rough, the lower smoother and of finer grains, the juncture a sharply defined lip or flange; wall thin, of subangular clear quartz grains 0.03 mm. and less in diameter, well cemented into a smooth, shiny surface; no aperture identified; color clear to slightly yellowish.

Dimension.—Greatest diameter 0.63 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—In addition to a general slight variation in the size of individuals in this species, several specimens are notably smaller—about two-thirds the diameter of the holotype. Since they are otherwise identical, it is probable that the two sizes represent a dimorphic species.

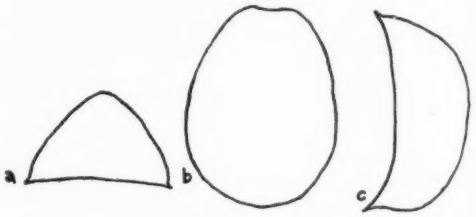
Holotype.—No. 22303, Geological Museum, Ohio State University.

FAIRLIELLA DICANTHA Summerson, n. sp.
Pl. 82, fig. 14

Test attached, single chambered, formed by two somewhat gently curving surfaces bordered by projecting flanges which in turn are separated by a concave surface, giving an overall irregular reel-like shape; wall thin, of fine subangular clear quartz grains 0.03 mm. and less in diameter; very well-cemented smooth surface with a high lustre; projecting flanges well developed into a smooth sharp wedge shape; no aperture apparent; color light yellowish.

Dimensions.—Longest diameter 0.41 mm., greatest height 0.17 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 4.



TEXT-FIG. 5—*Fairliella clitellata*, n. sp., outline sketches of holotype; *a*, end view; *b*, top view; *c*, side view. ×40.

Remarks.—The reel-like shape differentiates this species from others in the genus.

Holotype.—No. 22302, Geological Museum, Ohio State University.

FAIRLIELLA DISCOIDEA Summerson, n. sp.
Pl. 82, fig. 20; text-figs. 6a,b

Test attached, composed of a single chamber of flattened disk-like shape, with thin, biconvex walls. Upper surface curved, well cemented, slightly rough, sheen-like in appearance; lower surface less curved, thinner, and smoother; surfaces join at the periphery in a well-developed wedge-shaped flange. Grains are subangular clear quartz 0.03 mm. and less in diameter. No aperture apparent. Color clear to light yellow.

Dimension.—Greatest diameter 0.45 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—*Faireiella discoidea* is closely related to the planoconvex form *F. carmani* but is separated on the basis of the pronounced convexity of the lower surface.

Holotype.—No. 22304, Geological Museum, Ohio State University.

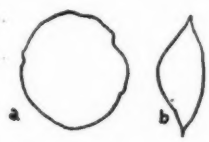
FAIRLIELLA LAMEYI Summerson, n. sp.
Pl. 82, fig. 21; text-figs. 7a,b

Test attached, large, single chambered, of flattened planoconvex shape with an elliptical outline; walls thin, very smooth, of extremely fine grains and a large amount of chitinous cement; surface somewhat lustrous; upper wall slightly thicker than lower; interior smooth; no aperture apparent; color deep brown.

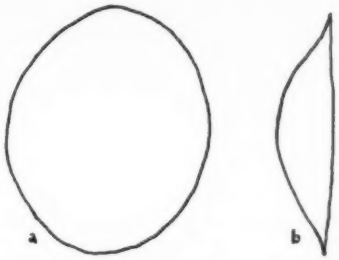
Dimension.—Greatest diameter 0.96 mm.

Occurrence.—Columbus limestone, Delhi member. Locality 1.

Remarks.—The generic identification of this species is questionable; it may belong in *Webbinella*, or it may represent a new genus. It is here included in *Fairliella* mainly because of the unusually fine grains and large amount of cement in the wall; the somewhat lesser degree of lustre than is typical of other species in this genus may be caused by the darker color.



TEXT-FIG. 6—*Fairliella discoidea*, n. sp., outline sketches of holotype; *a*, top view; *b*, cross section. ×40.



TEXT-FIG. 7—*Fairliella lameyi*, n. sp., outline sketches of holotype; *a*, top view; *b*, cross section. ×40.

Holotype.—No. 22306, Geological Museum, Ohio State University.

Family NEUSINIDAE Cushman, 1910
Genus SCHIZAMMINA Heron-Allen & Earland, 1929
SCHIZAMMINA sp.
Pl. 82, fig. 22

Test free, composed of irregular branches curving in several directions. Branches vary in diameter from 0.2 to 0.4 mm. and in cross section from circular to elliptical. Smaller branches are nearly solid; main branch contains an irregular cavity. Surface is smooth, of fine well-cemented quartz grains 0.03 mm. and less in diameter. Broken condition of specimen prevents any certain identification of aperture. Color white.

Occurrence.—Columbus limestone, Delhi member. Locality 3.

Remarks.—Although the only specimen found is broken and incomplete, it seems worthy of mention because it is distinctly different from any other form reported from the Devonian. Figured specimen No. 22307, Geological Museum, Ohio State University.

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TRILOBITES IN A PILLOW-LAVA OF THE ORDOVICIAN VALMY FORMATION, NEVADA[1]

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ABSTRACT—Trilobites collected from a limestone-filled pocket in a pillow-lava of the Ordovician Valmy formation are of Late Tremadoc or pre-Llandeilo age. The fauna includes *Shumardia*, *Apatokephalus*, *Trinodus*, and *Leiostegium*. Olenid trilobites have not been found although the facies may be considered favorable for their occurrence.

INTRODUCTION

IN THE course of geologic mapping of the Mt. Lewis quadrangle, Nevada, in 1950 James Gilluly and M. R. Mudge collected a rich trilobite fauna from limestone deposited in the voids between pillows of a greenstone. The greenstone, a local unit of the Valmy formation, is of Early Ordovician age. Because all previous dating of the Valmy formation has been on the basis of graptolites, this collection may have some value in establishing the relative stratigraphic position of some trilobite and graptolite zones.

The collection, given the number U.S.G.S. Fossil Locality 1273-CO, was made on the west side of Crum Canyon at an approximate elevation of 6400 feet in the center, $S\frac{1}{4}$, sec. 20, T. 30 N., R. 46 E, Mt. Lewis quadrangle, Nevada. Footage coordinates, based on the Nevada 10,000 foot grid are E 456,800 ft., N 2,075,800 ft.

Some parts of the enclosing limestone are coarsely crystalline with individual crystals up to 1.0 mm. in diameter. The coarser parts are highly fossiliferous, being composed largely of trilobite carapaces. Finer-grained limestone contains large gastropods, but few trilobites. A few simple conodonts have been obtained from the insoluble residue (formic acid), as well as one silicified articulate species and several inarticulate species of brachiopods.

Some surfaces of the limestone weather moderate yellowish brown and from a distance could be mistaken for weathered greenstone. Other surfaces weather light olive gray. On fresh surface the rock is medium gray. The complete lack of evidence for any contact metamorphism (Gilluly, 1957, oral communication) indicates that the fossiliferous carbonate sediments were deposited after the basalt pillows had cooled.

[1] Publication authorized by the Director, U. S. Geological Survey.

FAUNAL COMPOSITION AND CORRELATION

The collection of trilobites includes species of *Trinodus?*, *Apatokephalus*, *Leiostegium*, *Strigigenalis*, *Shumardia*, and *Pliomeroides* as well as a species congeneric with *"Isbergia" virginica* B. N. Cooper (1953). There are at least two other very small species that remain unidentified as to genus.

Collectively these species seem to indicate an early Early Ordovician age for the enclosing greenstones, which can be correlated with part of the Manitou limestone of Colorado, the lower part of the Garden City formation of Utah, and probably much of the Goodwin limestone as exposed on the east side of Antelope Valley, Eureka County, Nevada. In Wales, part of the Shineton Shales (Stubblefield and Bulman, 1927) contain *Trinodus*, *Apatokephalus*, and *Shumardia;* the same elements of the present fauna have been reported in the *Ceratopyge* beds of Norway (Brøgger, 1897; Størmer, 1920). The upper portion of the Lower *Planilimbata* limestone of Sweden contains a similar assemblage (Tjernvik, 1952; Wiman, 1905; Moberg and Segerberg, 1906). In Argentina some part of the pre-Caradocian sequence, of which the fauna has been described by Harrington (1937, 1938), and by Harrington and Leanza (1957), is certainly correlative. Although *Leiostegium* is considered Early Tremadoc by Harrington and Leanza (1957, p. 24), other elements are Late Tremadoc (1957, p. 28).

The Valmy trilobites are possibly correlative with those of the *Shumardia pusilla* zone of the Shineton Shales. This zone is above that of *Clonograptus tenellus*, which occurs in the highest Tremadoc, yet it is considered very low in the Ordovician succession (Stubblefield and Bulman, 1927, p. 117–120, correlation table facing p. 118). This possible correlation lends support to the dating based on poor graptolite material.

From shales which mapping has shown are from about the same stratigraphic position, Gilluly and Mudge also collected graptolites (U.S.G.S. Fossil Locality 1274-CO, approximately 400 ft. north of center of sec. 20, T. 30 N., R. 46 E.) which unfortunately are too poorly preserved to be identified positively. Josiah Bridge originally examined this collection and believed (preliminary report of identification, 1953) that the several fragments were those of dismembered *Didymograptus*, possibly of *D. extensus* (Hall), but also embodied features of *D. patulus* (Hall) and *D. nitidus* (Hall). If Bridge was correct and the specimens belong to any one or all three of these species the collection should be no younger than Llanvirn of the British section (Elles and Wood, 1914, p. 516,526). It is my belief that they probably do not belong to species that range above the Llandeilo.

During the past three years I have examined approximately 40 collections of graptolites made by Gilluly and co-workers from the Valmy formation of the Mt. Lewis and adjacent Crescent Valley quadrangles. The great majority of these are of Caradoc age, but 6 of them, plus 2 others examined by Bridge, seem to be of Arenig-Llanvirn age. Gilluly (oral communication, 1957) estimates that the lower Arenig-Llanvirn part of the Valmy formation may be as much as 9000 ft. thick in the Mt. Lewis quadrangle.

Yochelson has examined poorly preserved gastropods associated with the trilobites and identified them as a species belonging to *Proplina*. A second species he identifies as *Rhombella?* n. sp.

SIGNIFICANCE OF THE LITHOLOGY

In the immediate vicinity of this trilobite locality the Valmy formation is composed of bedded black chert, black shale and siltstone, greenstones with minor amounts of closely related limestone, and considerable thicknesses of clean quartzite of a type often termed "orthoquartzite." This combination of lithologies is incompatible according to some authors.

Mafic volcanic rocks are to be expected in a eugeosyncline according to Stille's original definition (1941, p. 15). On the basis of later

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EXPLANATION OF PLATE 83

FIGS. *1–4,7,14–16—Trinodus? valmyensis* Ross, n. sp. *1–4*, complete, enrolled specimen, holotype, cranidial, pygidial, anterior, and thoracic views, ×5, USNM 136142. *7*, pygidium, ×5, paratype, USNM 136149; *14–16*, smallest complete enrolled specimen found, anterior, cranidial, and pygidial views, ×5, paratype, USNM 136143.

5,6,8—Trinodus? sp. *5,8*, two pygidia showing expanded terminus of axial lobe, USNM 136155, 136156. *6*, large cephalon, showing suggestions of muscle scars on glabella and faint preglabellar median furrow, USNM 136154.

9–13—Apatokephalus gillulyi Ross, n. sp. *9*, cranidium, showing granulose surface and size of palpebral rim, ×2, paratype, USNM 136169; *10*, cranidium, showing features of occipital ring and indentations at front of glabella, ×2, paratype, USNM 136170; *11*, associated thoracic segment ×1, paratype, USNM 136172; *12*, pygidium showing characteristic denticulate margin, ×2, holotype, USNM 136168; *13*, pygidium, showing extent of ventral doublure, ×2, paratype, USNM 136171.

17—Shumardia aff. *S. minutula* Harrington. Cranidium, ×5, USNM 136173.

18—Pygidium of undetermined genus and species. May belong with cranidia figured in Pl. 84, figs. *6,8*, ×5, USNM 136174.

19,20—Leiostegium sp. *19*, cranidium, ×3, USNM 136166; *20*, pygidium, ×4, USNM 136167.

21–26—Leiostegium mudgei Ross, n. sp. *21*, cranidium, showing possible muscle scars on glabella, ×1, paratype, USNM 136158; *22*, rubber cast of cranidium showing double pits in dorsal furrow and shape of palpebral lobe, ×2, paratype, USNM 136159; *23*, free cheek, ×1, paratype, USNM 136165; *24*, small pygidium, showing 7 rings in immature axis, ×2, paratype, USNM 136162; *25*, holotype, cranidium, ×1, USNM 136157; *26*, large pygidium, ×1, paratype, USNM 136160.

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additions to this definition (Dapples, Krumbein, and Sloss, 1948, p. 1930,1942; Sloss, Krumbein, and Dapples, 1949, p. 99; Kay, 1951, p. 70–71,86) black shales or argillites and cherts characterize eugeosynclines while "orthoquartzites" are found ordinarily in a stable shelf environment.

The Valmy deposits indicate that quartzites in considerable volume are to be found in eugeosynclincal as well as shelf deposits.

SIGNIFICANCE OF THE FAUNA

In the Wrekin District of Wales a comparable trilobite fauna is present in "blue shale" of the Shineton Shales (Stubblefield and Bulman, 1929, p. 113) in an area of very complex structure. In Argentina (Harrington, 1938, p. 254–255,263–269) Upper Tremadoc gray and yellowish gray shales contain several elements of this fauna, although *Leiostegium* occurs in coarse grained, yellowish gray sandstone (p. 251) and light grey limestone (p. 252), both of Early Tremadoc age. According to Tjernvik (1952, p. 51,54,61) the *Trinodus-Apatokephalus-Shumardia* fauna near Nerike in Sweden is found in shale, intercalated in limestone which is correlative with the *Ceratopyge* limestone. In these places the fauna is clearly associated with a shale facies.

However, *Apatokephalus* is known from shelf limestone, as are *Shumardia* and *Trinodus*. Therefore, it seems that the fauna in question can be found in either a black shale or in a shelf limestone facies. However, *Leiostegium* is seldom found in shale and has not been previously reported in a eugeosynclinal facies.

In addition to *Leiostegium*, gastropods identified by Yochelson as a species of *Ozarkoconus* Heller and *Rhombella?* n. sp. add to the "shelf aspect" of the fauna.

EVIDENCE ON OLENID DISTRIBUTION

Wilson (1957, p. 322,324,325,335) has recently made the generalization that olenid trilobites are intimately related to eugeosynclinal, graptolite-bearing shales, argillites, and dark limestones, citing the Vinini formation (equivalent lithically and faunally to the Valmy formation) of Nevada as an example. The absence of olenids from the Valmy fauna here discussed and their presence in lower beds of the Goodwin formation in a shelf facies suggest that Wilson's generalization may need slight revision where it applies to the Ordovician of the Great Basin.

SUMMARY

The trilobite fauna of the lower part of the Valmy formation is of Early Ordovician age. Several of its genera (*Apatokephalus*, *Trinodus*, *Shumardia*) are found in a dark shale facies in northern Europe and Argentina, but are not limited to that facies. In

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EXPLANATION OF PLATE 84

FIGS. *1,2,13–15*—Undetermined genus and species No. 2. *1,15*, pygidia, both ×5, USNM 136179, 136183; *2*, cephalon with one broken and one slightly displaced free cheek, ×5, USNM 136180; *13*, free cheek, ×5, USNM 136181; *14*, cranidium, ×5, USNM 136182.

3,4—*Strigigenalis* sp. *3*, free cheek, ×3, USNM 136176; *4*, cranidium, ×3, USNM 136175.

5,7—*Pliomeroides* sp. *5*, rubber cast of obverse of specimen in fig. *7*, showing raised wire-like eye-ridge, ×2, USNM 136189b; *7*, decorticated cranidium, ×2, USNM 1361892.

6,8—Undetermined genus and species No. 1 (Congeneric(?) with "*Isbergia*" *virginica* Cooper, 1953). *6,8*, cranidia, both ×5, USNM 136177, 136178.

9,10—Undetermined proparian species. *9*, cranidium, ×2, USNM 136190; *10*, cranidium, ×3, USNM 136191.

11—Undetermined genus and species. Pygidium, probably assignable to one of two proparians illustrated above, ×3, USNM 136192.

12—Unidentified pygidium, ×5, USNM 136193.

16–19—Undetermined genus and species, No. 4. *16*, largest cranidium found, ×3, USNM 136185; *17*, associated free cheek, probably assignable to this species, ×5, USNM 136186; *18,19*, small cranidia, showing faint creases, comparable to glabellar furrows, ×5, USNM 136187, 136188.

20–22—Hypostomes, not identified. *20*, ventral view, ×2, USNM 136194; *21*, ventral view, ×3, USNM 136195; *22*, ventral view, ×2, USNM 136196.

23—Undetermined genus and species No. 3. ×2, USNM 136184.

addition, *Leiostegium* has not previously been reported from true eugeosynclinal beds and with two gastropods lends a "shelf aspect" to the fauna.

Olenid trilobites, which might be expected in this fauna, are as yet unknown in it.

SYSTEMATIC DESCRIPTION

The trilobite species of the Valmy formation are described below in hopes that other workers in the Americas may recognize this fauna and advise us of its distribution elsewhere.

Genus TRINODUS McCoy, 1846

Trinodus McCoy, 1846, p. 56–57.
Trinodus McCoy, Kobayashi, 1939, p. 174 (in part).
Trinodus McCoy, Howell, 1935, p. 234 (in part)

Three species included by Kobayashi (1939, p. 174–175) in this genus do not conform to the rest and probably should be excluded. The front of the glabella of "*Agnostus*" *fabius* Billings is not encompassed by the dorsal furrows, differing drastically from species of this genus. *Agnostus dusli* Novak (1884) was described only from a pygidium lacking the elongate tubercle on the pygidial axis and possessing a strongly papillose surface. *Agnostus lentiformis* Angelin (1854, pl. 6, fig. 6) possesses a very different type of pygidial axis.

The best illustrations of the manner of enrollment of *Trinodus* are given in a series of line drawings by Jaeckel (1909, figs. 1–6). The first photographs of complete enrolled individuals are presented here.

Revised description.—The surface of the carapace is smooth or reticulated. The cephalon is subsemicircular to U-shaped in outline. The tapering glabella is rounded anteriorly and bounded laterally and in front by confluent dorsal furrows. Transglabellar furrows are lacking or suggested by faint impressions adjacent to the dorsal furrows. Two nodes or lobes are present at the base of the glabella interrupting the course of the dorsal furrows. The furrow bounding the front of the basal lobes and crossing the rear of the glabella in a backward curve seems to be analogous to the occipital furrow of other trilobites. Behind this furrow the occipital ring is represented by a narrow (sagittally) flattened strip; the basal lobes are lateral expansions on this strip (pl. 1, fig. 15).

A small median node may be present on the glabella. The pleural lobes are evenly convex and slope downward to a marginal furrow. The border is narrowly convex and wider (sagittally) in front than postero-laterally. When present the genal spines are short cones or nubs set off by furrows across their bases.

The axial lobe on each thoracic segment is bounded by dorsal furrows converging sharply anteriorly. A large boss or node lies outside the dorsal furrow on either side and appears to be structurally analogous to the basal lobe of the glabella on the cephalon. These bosses are separated from the ends of the segments by furrows (pl. 1, fig. 4; Jaeckel, 1909, fig. 1).

The pygidial outline is similar to that of the cephalon, as is the configuration of the pleural lobes. The axis is bounded laterally by dorsal furrows which are confluent around the rounded terminus. Three transverse segments compose the axis. Resting on the crests of the first two segments is an elongate node, interrupting the transverse furrow between the first and second segments. The narrow, convex border may bear a pair of postero-lateral spines.

TRINODUS VALMYENSIS Ross, n. sp.
Pl. 83, figs. 1–4,7,14–16

Surface smooth. Cephalon as wide as long. Border distinct and bounded proximally by a deep marginal furrow. Cheeks strongly convex. Glabella convex but low. Slight constriction one-third of the length from the front creases its sides; transverse furrow lacking. Distinct but small node surmounts the anterior third. Genal spines represented by rounded nubs. Glabella tends to be a little more than half as long as cephalon and a little more than a quarter as wide. Its width is approximately two-thirds its length.

Pygidium about as wide as long, bearing a pair of very small postero-lateral spines on border. On some specimens these spines nearly non-existent. Elongate node rests on first two segments of axis; this node very low over the anterior segment but strong over the second. Axis about half as long as the pygidium.

Holotype.—USNM 136142.

Paratypes.— USNM 136143–136149, 136151, 136152.

Several measurements for this species may be of use to future investigators. These are based on a statistically inadequate sample, 4 complete specimens, 4 separate cephalons, and 2 separate pygidia.

Trinodus? valmyensis Measurements on 4 complete specimens, 7 cephalons, and 4 pygidia, all measurements in mm.	USNM Numbers									
	136142 (Plate 83, figs. 1–4)	136143 (Plate 83, figs. 14–16)	136144	136145	136146	136147	136148	136151	136152	136149 (Plate 83, fig. 7)
Length of cephalon	2.6	1.8	2.2	2.3	2.0	2.5	2.5	2.5		
Width of cephalon	2.7	1.8	2.5	2.3	2.0	2.4	2.4	2.6		
Length of glabella exclusive of occipital ring	1.5	1.1	1.3	1.3	1.2	1.4	1.4	1.4		
Width of glabella exclusive of basal glabellar lobes	1.0	.75	.9	.8	.8	.9	.9	.9		
Width of glabella at basal glabellar lobes	1.7	1.0	1.3	1.3	1.2	1.2	1.5	1.3		
Midlength of preglabellar field	.8	.6	.7	.6	.7	.6	.6	.6		
Length of pygidium	2.6	1.5	2.0	2.2					2.3	2.7
Width of pygidium	2.7	1.8	2.5	2.2					2.3	2.7
Length of pygidial axis	1.6	1.0	1.3	1.5					1.5	1.6
Width of axis at 1st segment	1.2	.7	1.0	.9					1.0	1.2
Width of axis at 2d segment	1.0	.6	.8	.8					.85	1.0
Width of axis between 2d and 3d segments	.92	.58	.76	.8					.7	.8
Width of axis at 3d segment	.94	.62	.76	.8					.75	.9

T. valmyensis resembles *T. longicollis* (Raymond) (1925, p. 12–13, pl. 1, figs. 5,6) in the possession of a small tubercle well forward on the glabella and very small postero-lateral spines. That species has a finely reticulated surface and a longer pygidial axis.

T. tardus Barrande, *T. chinianensis* Howell, *T. fossulatus* Moberg and Segerberg, *T. galba* (Billings), and a specimen called *Agnostus trinodus* var. by Moberg and Segerberg (1906, p. 78, pl. 4, fig. 5) lack postero-lateral spines on the pygidium and in this respect differ from the species described here. However, Whittington (1950, pl. 68, figs. 4–6) illustrates specimens assigned to *Trinodus tardus* (Hawle and Corda) which possess the postero-lateral spines.

Several species possess pygidial axes which are much shorter relative to the overall length of the pygidium, i.e., *Trinodus tardus* Barrande, *T. corpulentus* Howell, *T(?). fossulatus* Moberg and Segerberg, *T. erraticus* Jaeckel, *T. mobergi* Tjernvik, *T. elliptifrons* Tjernvik, and a form called *Agnostus trinodus* by Olin (1906, pl. 4, figs. 15,16).

Two species, *Trinodus juyjuyensis* Harrington and *T. glabratus* Angelin, possess pygidial axes of essentially the same relative length as that of *T. valmyensis*.

T. abruptus Howell has a truncated glabella unlike *T. valmyensis*. The narrowness of the glabella relative to the width of the cephalon distinguishes *T. agnostiformis* McCoy (Whittington, 1950, p. 533–534, pl. 68, figs. 1–6), *T. juyjuyensis* Harrington, and *T. erraticus* Jaeckel from this species.

T. elspethi (Raymond) (Cooper, 1953, p. 7–8, pl. 1, figs. 1–12) is a much larger species, with strong genal spines, strong postero-lateral spines, and a granulated surface.

The faint constriction at the front of the glabella probably represents the relict transglabellar furrow of *Geragnostus*. *T.*

galba (Billings) has the same type of glabellar constriction (Billings, 1865, p. 297, fig. 288). This species may be intermediate between *Geragnostus* and typical *Trinodus*.

Harrington (1938, p. 163) and Harrington and Leanza (1957, p. 73–74) note that the pygidium of *Trinodus juyjuyensis* Harrington resembles more closely that of *Geragnostus rudis* Salter than those of typical *Trinodus*, the axes of which are usually shorter. The pygidial axis of the new species *T. valmyensis* Ross is of about the same length as the Argentine species.

Harrington and Leanza (1957, p. 74) have described *Trinodus? saltaensis* and have considered it intermediate between *Geragnostus* and true *Trinodus* because it retains traces of a transglabellar furrow. For the same reason *T. valmyensis* might be considered intermediate. The constriction which may represent a relict(?) furrow is placed much farther back than in *T?. saltaensis*, thereby resembling the furrow of *Geragnostus* more closely than does that of the Argentine species.

TRINODUS? sp.
Pl. 83, figs. 5,6,8

Associated with *Trinodus valmyensis*, n. sp. is a species characterized by a long pygidial axis, the terminal segment of which is markedly expanded. The axis is a little more than two thirds as long as the pygidium. The terminal segment is as wide as the first segment of the axis.

No cephalons can be distinguished as surely belonging to this species. Three have been separated on statistical grounds only; one of these is illustrated in plate 83, figure 6. In each of the three specimens the glabella is about two thirds as long as the cephalon whereas it tends to be a little more than half as long as the cephalon in *T. valmyensis*. There is also a tendency for the glabella to be a little wider relative to the width of the cephalon. However, both of the seeming differences are based on such small samples that they are highly unreliable. Two possibilities should not be overlooked, (1) the cephalons of this species may not be separable from those of *T. valmyensis*, or (2) none have yet been separated in the present collections.

The general shape of the pygidial axis is similar to those of several species of *Geragnostus*, such as *G.* (*Micragnostus*) *vilonii* Harrington and Leanza, *G.* (*M.*) *callaveiformis* Harrington and Leanza, and *G. tumidosus* (Hall and Whitfield). If the cephalon of this species proves to be *Trinodus*-like it may be intermediate between *Trinodus* and *Geragnostus* as regards the pygidium. If not, the subject pygidia may belong to a species of *Geragnostus*, specimens of the cephalon of which have for some reason escaped our searches.

Figured specimens.—USNM 136154–136156.

Measurements of two pygidia and three cephalons are tabulated:

Trinodus? sp. All measurements in mm.	USNM Numbers				
	136153	136150	136154 (Plate 83, fig. 6)	136155 (Plate 83, fig. 5)	136156 (Plate 83, fig. 8)
Length of cephalon	2.6	2.5	3.1		
Width of cephalon	2.6	2.7	3.5		
Length of glabella exclusive of occiptal ring	1.7	1.6	1.95		
Width of glabella exclusive of basal glabellar lobes	1.1	1.1	1.3		
Width of glabella at basal glabellar lobes	1.7	1.6	2.0		
Midlength of preglabellar field	.7	.5	1.0		
Length of pygidium				2.8	2.2
Width of pygidium				2.9	2.5
Length of pygidial axis				2.0	1.6
Width of axis at 1st segment				1.3	1.1
Width of axis at 2d segment				1.2	1.0
Width of axis between 2d and 3d segments				1.1	.9
Width of axis at 3d segment				1.3	1.1

Genus LEIOSTEGIUM Raymond 1913
LEIOSTEGIUM MUDGEI Ross, n. sp.
Pl. 83, figs. 21–26

Surface of carapace smooth. Cephalon semicircular in outline with short, stout genal spines. Border convex and ornamented with circumscribed Bertillon markings. Marginal furrow deep.

Glabella tapering anteriorly. Its front rectilinear, bounded by the marginal furrow. The dorsal furrows are straight or very slightly curved so as to give the glabella a constricted appearance. On each side a deep pit is located at the intersection of the dorsal and marginal furrow; a second more shallow pit is behind the first in the dorsal furrow (pl. 83, figs. 21,22,25). Palpebral lobes are short and crescentic, bounded proximally by shallow palpebral furrows. No evidence of eyelines on any of the specimens examined.

Pygidium wider than long, semi-elliptical in outline. Border convex, marginal furrow shallow. Axis of five rings plus an unsegmented or very faintly segmented terminal part. Axis markedly wider at the front on large than on small specimens. Pleural platforms gently convex.

Holotype.—USNM 136157.

Paratypes.—USNM 136158–136165.

This species is represented by far too few specimens to permit an adequate statistical analysis. However inadequate they may be, a few measurements may give a better idea of the spread of variation than none at all. Comparison with other species is hampered by the lack in most descriptions of any statistics for them.

Pygidia of *Leiostegium douglasi* Harrington (1937, p. 114), for which measurements are given and (1938, pl. 6, figs. 1–5, 8) those which are illustrated agree so closely in relative length and width that they cannot be distinguished in that respect from the present species. The pygidial axis of the Argentine species is considerably narrower in mature specimens although its width is the same for immature specimens of both species. For any given length of pygidium the length of the axis tends to be 1.5–2.0 mm. longer in *L. douglasi* and *L. manitouensis* than in this species.

Pygidia more than 12 mm. long tend to be narrower than those of *L. manitouensis*, and those less than 12 mm. long tend to be wider. This tendency is, however, statistical and enough variation occurs in both species to make their distinction difficult or nearly impossible on this basis.

The semielliptical outline of the pygidium of the present species differs from the subtriangular shape of *L. manitouensis*.

L. obtectum (Raymond) and *L. elongatum* Raymond are known only from pygidia both of which possess much narrower borders than the present species. The pygidium of *L. elongatum* is markedly triangular. The pygidial axis of *L. obtectum* possesses fewer distinct rings and is wider than that of the present species.

The anteriorly tapering glabella is found in only a few species of *Leiostegium*. In *L. puteatum* Raymond (1924, pl. 14, figs. 12,19) the glabella is parallel sided or a little wider toward the front. That of *L. cingulosum* Raymond (1924, pl. 14, figs. 18,21) is similar to that of *L. puteatum* and its pygidium is

Cranidia: (measured in mm.)

	USNM 136157	USNM 136159	USNM 136158
Length of cranidium	11.6		
Length of glabella	10.6		13.7
Width of glabella at front	5.5	4.3	8.3
Width of glabella at occipital ring	7.5		10.0
Width of cranidium at palpebral lobes	14.7	10.4	15.8
Width of cranidium at postero-lateral limbs	20.5		

Pygidia:

	USNM 136160	USNM 136161	USNM 136162	USNM 136163	USNM 136164
Length	26.0	10.5	6.8	17.1	7.5
Length of axis	21.0	7.9	6.2	13.3	5.8
Width	39.0	15.7	11.2	24.0	14.6
Anterior width of axis	12.2	4.4	3.4	6.5	2.6

considerably wider for its length. The glabella of *L. quadratum* Billings (1865, p. 412, fig. 396) differs from the present ones in its shortness and in its forward widening. Although the glabellas of both *L. manitouensis* and *L. douglasi* taper forward, both are rounded at the front and not so abruptly terminated by the marginal furrow. There is only one pair of pits in the dorsal furrow of *L. douglasi* (Harrington, 1937, p. 113–114; Harrington and Leanza, 1957, p. 81), whereas there are two pairs in *L. mudgei* (pl. 1, figs. 21,22,25). *L. formosum* Hintze has a pustulose surface and like *L. glabrum* Kobayashi a pair of postero-lateral spines on the pygidial border. *L. glabrum* differs also in having a forwardly expanding glabella and a smooth surface.

LEIOSTEGIUM sp.
Pl. 83, figs. 19,20

Only two cranidia and two pygidia, all very small, were found. This species has a sparsely pustulose surface. The outline of the glabella compares favorably with that of *L. manitouensis*. The palpebral lobes seem larger than those of any other species of *Leiostegium*. However, relatively large eyes are characteristic of immaturity in trilobites and small size suggests that these specimens are immature.

The pygidium possesses five clearly defined axial rings, and spacing of pustules suggests that there may be four additional segments in the posterior portion of the axis, not delimited by furrows.

If a pair of spines were added to the border of the pygidium, it might pass for *L. formosum* Hintze.

Figured specimens.—USNM 136166, 136167.

Genus APATOKEPHALUS Brøgger, 1897
APATOKEPHALUS GILLULYI n. sp.
Pl. 83, figs. 9–13

Surface of cranidium granulated. Pits in marginal furrow. Border or rim narrowly convex. Glabella with 3 pairs of glabellar furrows none of which meet across the midline. Front pair originates at front end of palpebral furrow running posterioproximally for a short distance. Second pair is a little longer than the first and slightly curved. Although posterior pair in some species of *Apatokephalus* is sigmoid and contiguous or nearly contiguous at the midline, only distal half of the "S" is present in this species, with its convex side forward. Occipital furrow deep; a quadrate area is crudely defined by subsidiary furrows near midline in same manner as on thoracic segments. Median pustule present on occipital ring.

Palpebral rims well developed; their length six-tenths that of glabella. Course of palpebral furrow distally convex in front but concave behind. Between front ends of palpebral lobes glabella is constricted, and expands again to preglabellar furrow. Preglabellar furrow does not follow even curve but is indented gently on either side of midline.

Thoracic segments bear characteristically falcate pleura, with groove running sinuously from axial furrow at front to the tip.

Pygidium composed of pointed axis of four rings and semiconical terminus. Between two pairs of broad, pointed pleura is area which seems to be crossed by three pairs of pleural or interpleural "ridges" and which bears at least eleven pairs of minute denticles along rear edge.

Holotype.—USNM 136168.

Paratypes.—USNM 136169–136172.

In this species the constriction of the glabella between the fronts of the palepbral rims gives it an elongate appearance which resembles *A. dubius* (Linnarson) as figured by Brøgger (1897, fig. 5a) not as figured by Harrington (1938, pl. 5, figs. 6,8). The outline of glabella and the type of pygidium is quite different from that of *A. finalis* (Walcott), another Nevada species. Only *A. pecten* Wiman (1905, p. 6–7, pl. 1, figs. 7–12) has similar denticles on the pygidium but its axis is composed of only one ring plus terminus. The glabella of *A. pecten* possesses only two pairs of glabellar furrows. In *A. serratus* (Boeck) the glabella is not constricted at the front of the palpebral lobes and the anterior pair of glabellar furrows is transverse. The pygidium has five pairs of pleural spines. *A. canadensis* Kobayashi (1953, p. 52, pl. 3, figs. 1–4) differs from *A. gillulyi* Ross for the same reasons as *A. serratus* with which it may prove to be synonymous. *A. exiguus* Harrington and Leanza possesses a broader and shorter glabella and much shorter pygidial axis.

Genus SHUMARDIA Billings, 1862

SHUMARDIA sp. aff. S. MINUTULA Harrington

Pl. 83, fig. 17

Shumardia minutula Harrington, 1938, p. 216–218, pl. 9, figs. 6,8,13,15,16.

The present species is known from one cephalon. The specimen which it seems to resemble most closely is one of *S. minutula*, illustrated by Harrington (1938, pl. 9, fig. 15).

The central part of the glabella of this species tapers toward the front. The small lateral lobes are so shaped and arranged as to give the whole the shape of a cross. Almost all figured specimens of other species show that the front of the glabella including the lateral lobes has a rounded outline (*S. nericiensis* Wiman, *S. dicksoni* Moberg, *S. bottnica* Wiman) or a shape something like a very blunt spear or arrowhead (*S. pusilla* Sars, *S. velandica* Moberg, *S. erquensis* Kobayashi).

S. granulosa Billings belongs with the latter on the basis of its glabella, but has a preglabellar (saggittal) furrow as does the present specimen. *S. minutula* which is closest to our present specimen in shape of glabella lacks a preglabellar furrow.

No attempt is made to name or fully describe this species until more and better examples are obtained.

Figured specimen.—USNM 136173.

Genus STRIGIGENALIS Whittington and Ross, 1953

STRIGIGENALIS sp.

Pl. 84, figs. 3,4

A single cranidium was obtained which is referable to this genus. It is so small that a comparison with *S. cassinensis* Whittington or *S. abdita* Ross is probably impractical. It bears a suggestion of en eyeline from the front of the palpebral lobe to a point of tangency with the glabella, a feature not found in either of the other species. However, this may only be an immature feature.

Figured specimens.—USNM 136175, 136176.

S. cassinensis is from the Cassin formation of Cushing (1905, p. 362) at Fort Cassin, Vermont. *S. abdita* is from Ross's zone G(2) of the Garden City formation. From this it is probable that the present specimen is of Early but not earliest Ordovician age.

Associated free cheeks assignable to the genus are too large to belong to the figured cranidium; they probably belong to the species nonetheless.

Undetermined genus and species No. 1

Pl. 84, figs. 6,8

Surface smooth. Glabella subpyriform, strongly convex, expanding forward. Glabellar furrows absent or very faint. Two pairs present on some specimens (pl. 2, fig. 7). Occipital furrow strong; occipital ring widest (sagittally) at the midline. Glabella standing well above fixed cheeks. Dorsal furrows shallow but distinct, confluent in a broad curve around front of glabella.

Preglabellar field steeply sloping to shallow marginal furrow and narrow flattened border. Fixed cheeks very narrow. Palpebral lobes small, subcircular, convex, and located well forward (pl. 84, fig. 6).

Facial sutures diverge in front of palpebral lobes. Behind the lobes the sutures bound broad "postero-lateral limbs." Free cheeks not identified.

Neither the thorax nor pygidium is known. However, a pygidium illustrated in plate 83, figure 18 may belong to this species.

Figured specimens.—USNM 136177, 136178.

This small species is probably congeneric with "*Isbergia*" *virginica* Cooper from the Effna limestone of Cooper (1944, p. 59–64), but it is probably not congeneric with either species on which Warburg based the genus *Isbergia*.

The flattened cephalic border of this species is wider than that of "*I.*" *virginica*. It has one and sometimes two pairs of glabellar furrows very similar to the single pair of the Virginia species.

Neither of these species agrees with Warburg's concept of *Isbergia* (Warburg, 1925, p. 186–187). Both species assigned by her have unfurrowed glabellas, which taper anteriorly, and rather long eyes. These differences outweigh the similarities.

Undetermined genus and species No. 2

Pl. 84, figs. 1,2,13,14,15

The second most common species in the present collection is a small, smooth form which may be represented only by immature specimens. Its affinities are not known,

although it bears several resemblances to illaenids. Until the stage of growth of these specimens can be established erection of a new species or genus seems unwise.

The surface is smooth. Convexity of both cephalon and pygidium is low. The cephalon is semicircular in outline with stout genial spines. Neither a glabella nor pygidial axis is defined by dorsal furrows except at the very rear of the cephalon and front of the pygidium. Even so no real furrows are present. There is no occipital furrow. A relatively wide, flat border runs from the tip of one genal spine around the front of the cranidium to the tip of the other spine. The facial sutures outline exceptionally inconspicuous palpebral lobes from which they run nearly straight forward to cross the border. Behind the lobes the sutures delimit postero-lateral limbs similar to those of *Dysplanus*.

The eyes are large, and rest on small ocular platforms. Each genal spine is thick proximally, particularly along the postero-proximal side. The free cheeks also resemble those of *Dysplanus*.

The surface of the pygidium slopes smoothly to the edge without trace of marginal furrow or border.

Figured specimens.—USNM 136179–136183.

The almost featureless pygidium and small palpebral lobes are similar to those of *Dysplanus* and *Illaenus* but I have found no record of an illaenid species possessing a similar border on the cephalon. For one or more of these same reasons the species does not agree with the accepted concept of *Nileus* or *Symphysurus*.

Because all the specimens are very small (the largest cranidia and pygidia are about 3 mm. long), the possibility must be seriously entertained that these are only young stages of some unrecognized species. Genal spines present on immature specimens may be lost in mature stages. Whether the flattened margin would be converted and how it would be converted during growth we cannot tell.

That there should be no adult specimens of this species anywhere in the collection seems peculiar.

Undetermined genus and species No. 3
Pl. 84, fig. 23

This interesting pygidium possesses a semiconical axis of 3 well developed rings plus a constricted terminus. The pleural platforms are crossed by 3 sinuous main ribs which project beyond the border as large backward pointing spines. Between any two of these main ribs is a short rib reaching to the border. The convex border is bounded proximally by a much-interrupted marginal furrow.

Figured specimens.—USNM 136184.

This pygidium bears a resemblance to those of species of *Hysterolenus* and *Ceratopyge*, differing in having fewer axial rings and a greater number of spined pleural ribs.

Undetermined genus and species No. 4
Pl. 84, figs. 16–19

This species possesses a strongly convex, somewhat inflated glabella, subrectangular in outline with a rounded front. There is no preglabellar field, since the front of the glabella drops abruptly into the marginal furrow. The occipital furrow is deep, delimiting a short (sagittally) occipital ring. On the smaller specimens three pairs of very faint grooves mark the sides of the glabella. I am reluctant to call these glabellar furrows in the usual sense, because of their faintness. The posterior pair runs postero-proximally from the dorsal furrows. The middle pair is oriented at right angles to the dorsal furrow. The front pair runs antero-proximally from the dorsal furrow.

Each dorsal furrow is deeply impressed and confluent with marginal furrow around the front of the glabella. The border is very narrow and slightly convex.

The fixed cheeks must be very narrow; in all specimens the palpebral lobes have been broken, but they are believed to have been small and close to the glabella. As far as I can now tell, the facial stuures seem to run straight forward from the palpebral lobes to the marginal furrow; there they turn inward to cross the border. Behind the palpebral lobes the sutures diverge strongly, then turn sharply and cross the posterior marginal furrow and border a distance from the dorsal furrow equal to 6/10–7/10 the occipital width of the glabella. The posterior

marginal furrow is not an extension of the occipital furrow.

Two small specimens illustrated (pl. 84, figs. 18,19) show faint grooves comparable to glabellar furrows. The largest specimen found (pl. 84, fig. 16) has no such grooves and a more inflated glabella. At present these differences are not considered grounds for separate species because the smaller specimens may be immature.

The free cheek illustrated in plate 84, figure 17 is thought to belong to this species but assignment is indefinite. The steep slope of the front part of the fixed cheeks and the postero-lateral limbs agrees well with the convexity of the ocular platform of the free cheek. However, the strong Bertillon lines of the border are not shown on the borders of two of the cranidia and show only faintly on the one illustrated in plate 84, figure 18.

Figured specimens.—USNM 136185–136188.

This species bears a resemblance to *Theodenisia communis* (Rasetti), (1954, p. 607–609, fig. 3b), but differs in the possession of a well developed anterior border not overhung by the glabella and narrower fixed cheeks.

Genus PLIOMERIODES Harrington and Leanza, 1957

PLIOMEROIDES sp.

Pl. 84, figs. 5,7

Surface of glabella smooth; that of fixed cheeks pitted. Glabellar outline subrectangular. Three pairs of glabellar furrows, all oriented with distal ends anterolateral and proximal ends posterocentral. The front pair intersects the dorsal furrow behind the anterior "corner" of the glabella. In the single decorticated specimen there is a median preglabellar depression in the marginal furrow.

Opposite the intersection of the front glabellar furrows and dorsal furrows the ocular ridges start from the outer side of the dorsal furrow, running sideward and backward across the fixed cheeks to the eyes. These ridges are very slender except for a slight expansion at the distal ends. These are differently located than in *Protopliomerops* and *Rossaspis*, since the anterior side is not bounded by the marginal furrow.

The genal angles bear stout spines, considerably shorter than those of the type species.

The thoracic segments have not been identified for this species. The only associated pygidium which is of a type ordinarily found in proparian trilobites is illustrated in plate 84, figure 11. This pygidium possesses 5 pairs of digitate spines projecting backward from the border. The axis is relatively narrow; because of poor preservation the number of rings is not known.

Figured specimen.—USNM 136189a, 136189b.

Only one specimen has been found of this species. The other proparian species reported below differs in the possession of rounded anterior corners of the glabella, having the front pair of glabellar furrows bisect the "corners" rather than originating behind them, and in having glabellar lobes isolated by the curving posteroproximal ends of the rear pair of furrows and in one specimen by the middle pair. Even if allowance is made for the fact that the one specimen of *Pliomeroides* is decorticated while the specimens of the other species are not, these differences cannot be reconciled.

This species differs from *P. deferrariisi* Harrington in its parallel sided rather than tapering glabella, and in much shorter genal spines.

Unidentified Proparian species

Pl. 84, figs. 9,10

Two proparian specimens differ from *Pliomeroides* sp. in possession of a glabella with rounded anterior "corners" and glabellar furrows which tend to isolate the posterior and middle glabellar lobes. On both of these the anterior glabellar furrows bisect the anterior corners of the glabella. The eye ridges are very fine, raised "threads," slightly expanded at the distal ends.

No thoracic segment or pygidium is known for this species. However, the pygidium figured on plate 84, figure 11 may belong here rather than with *Pliomeroides* sp.

Figured specimens.—USNM 136190, 136191.

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AN EMBOLOMEROUS AMPHIBIAN IN THE GARNETT FAUNA (PENNSYLVANIAN) OF KANSAS

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ABSTRACT—A neural arch and scapulocoracoid of an embolomerous amphibian, *Hesperoherpeton garnettense*, n. gen. and n. sp., is described from the Late Pennsylvanian of Kansas, and referred to the family Cricotidae. This is the first amphibian to be represented by skeletal remains in the Garnett fauna, and strengthens the opinion that a Carboniferous stream or streams rafted terrestrial organisms into a lagoon and into association with marine organisms.

INTRODUCTION

THE presence of amphibians in the Garnett fauna (Peabody, 1952, 1957) of Upper Pennsylvanian age, in eastern Kansas, has long been questioned. In 1950, Professor H. H. Lane of the University of Kansas related (personal communication) that field work in the 1930's had discovered a series of nectridian vertebrae at Garnett, but these subsequently disappeared and may be presumed lost. Field work directed by myself in 1953 and 1954 uncovered many excellent trackways of what appear to be large eryopsoid amphibia, but skeletal remains of amphibia remained conspicuously absent. Then, in 1955, routine laboratory preparation of slabs containing reptiles obtained in 1954 brought to light some tiny bones of dark amber color, unmistakably amphibian, but not nectridian. The bones occurred near the floor of the Pennsylvanian lagoon, close to the shore line, in a highly carbonaceous facies, and associated closely with petrolacosaur, ophiacodont and edaphosaurian reptiles (see Peabody, 1957).

The amphibian bones consist of a complete scapulocoracoid associated with a neural arch straddling the glenoid region. The specimen was prepared so that both sides could be studied. A slender rib fragment lies close by, and two unidentified fragments of bone closely adhere to the median aspect of the scapulocoracoid. Probably all the bones belong to one individual. Since our preparation techniques were adjusted early to the occurrence of delicate insects and plants in the strata, it seems unlikely that other parts of the amphibian were overlooked.

In view of the amphibian's importance to the Garnett fauna and the rarity of Pennsylvanian amphibians west of the Mississippi River, a new name is proposed. Miss Hermine Newcombe assisted with the illustrations; Miss Madeline Peabody assisted with the manuscript.

Class AMPHIBIA
Superorder LABYRINTHODONTIA
Order ANTHRACOSAURIA
Suborder EMBOLOMERI
Family CRICOTIDAE

HESPEROHERPETON GARNETTENSE, n.gen. and n. sp

Text-fig. 1

Holotype.—University of Kansas Museum of Natural History no. 9976, (shown in text-fig. 1); a right scapulocoracoid and neural arch in close association.

Diagnosis.—A small embolomerous amphibian with short neural spines in the dorsal region; with scapulocoracoid 14.5 mm. in the greatest diameter, and characterized by an unusually broad, posterior coracoid region, a low set supraglenoid foramen, and a triangular glenoid surface of "unfinished" bone.

Age and horizon.—Upper Pennsylvanian near Garnett, Kansas, Rock Lake shale member, Stanton formation (Peabody, 1952, 1957).

Description.—The scapulocoracoid is complete except for a part of the anterior scapular margin inadvertently lost in preparation. The neural arch obscures the posterior glenoid, and thin fragments of bone occupy the cavity of the subscapular fossa but do not obscure its margins. On the lateral surface, a break through the supraglenoid buttress has caused a small displacement. Other than as noted above, the specimen is ex-

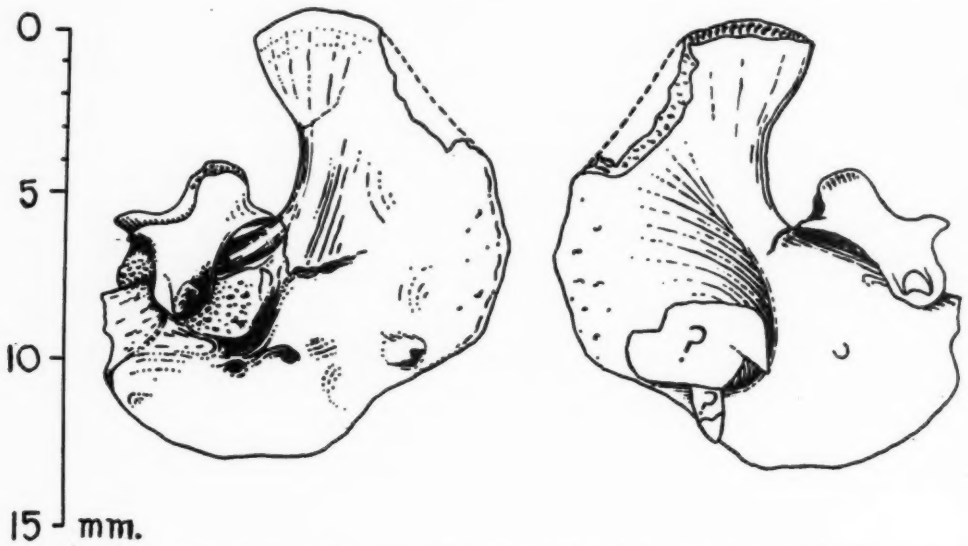
cellently preserved in spite of its tiny dimensions.

The neural arch appears to consist of separate halves pressed together. The left side is complete; the right is damaged slightly from preparation. Strong development of the laterally directed diapophysis indicates an anterior dorsal position in the vertebral column, and the nearly symmetrical wedge formed by the pedicel of the neural arch indicates articulation with the discoid pleurocentrum and intercentrum of an embolomerous vertebra. The neural spine is short—otherwise there are no special characteristics. However, the neural arch by association aids identification of the scapulocoracoid.

General contours of the scapulocoracoid are shown in figure 1, and correspond to Romer's (1957, p. 107) general description for *Archeria*. The bone is clearly that of a primitive amphibian—a short scapular blade expanded anteriorly, passing downward into a broad coracoid plate with no evidence of a suture between. A supraglenoid foramen (its aperture narrowed by crushing), a small coracoid foramen anteroventral to the glenoid, and a still smaller foramen below the glenoid are clearly seen in lateral view; median openings of these foramina are not surely located because of occlusion of the subscapular fossa noted above, and because of minute patches of matrix too difficult to remove. A small external tubercle near the anteroventral margin of the coracoid is apparently a distortion caused by pressure from an unidentified piece of bone lying on the median surface.

The posterior coracoid region is characterized by a flattened glenoid surface of "unfinished" bone hidden posteriorly by the straddling neural arch. The glenoid surface appears more triangular than strap-shaped, and is inclined at approximately 40° to the coracoid surface. A triangle of extremely thin bone forms the posterodorsal area of the coracoid and is set off by a distinct step leading anterodorsally from the posterior margin of the coracoid to the posterior margin of the glenoid. The thin area is not so set off on the median surface; possibly there was an area of cartilage, backed by the thin bone medially, and occupying the triangular area in the lateral aspect of the scapulocoracoid, and possibly contributing to a posterior part of the glenoid surface.

Remarks.—The bones here described are believed to represent one individual for several reasons. The relative size is approximately correct; the color and texture is



TEXT-FIG. *1*—External view (left) and median view (right) of the scapulocoracoid and neural arch of *Hesperoherpeton garnettense*.

similar and differs from pelycosaur bones found several inches away and at the same level; long and careful collecting over a wide quarry area has failed to discover other parts or other amphibia. If this conclusion be accepted, then the neural arch astride the scapulocoracoid is a fortuitous association, for the contours of the diapophysis and the pedicel strongly suggest the double disc vertebra of an embolomere. The neural arch with its low spine is similar to that of embolomeres described by Steen (1934, fig. 176) from Pennsylvanian coal swamps of Nova Scotia (*Calligenethlon* Romer, 1947) except that parapophyses are not shown by Steen—they were probably damaged or lost.

The scapulocoracoid is clearly of a primitive type consonant with the neural arch, and in the "unfinished" surface of the glenoid indicates the presence of much cartilage at the shoulder joint. This suggests an aquatic mode of life for the amphibian. In this respect, there is similarity with cricotid embolomeres, for example, *Archeria* which has an "unfinished" glenoid. By contrast, terrestrial microsaurs from the Lower Permian, *Cardiocephalus* (Gregory *et al.*, 1956, p. 51), have precisely finished glenoids although only half the body size of our small embolomere.

Comparison of the scapulocoracoid with that of *Archeria*, a much larger amphibian (Romer, 1957, fig. 1), is helpful in establishing a general similarity. However, there are several significant differences. In *Archeria*, The supraglenoid foramen is higher above the glenoid although there are two foramina in the coracoid plate similarly placed. The glenoid is strap-shaped and more extensive posteriorly whereas in our specimen a thin plate forms the posterior end of the coracoid and the glenoid is limited to a triangular rather than strap-shaped area. Possibly this is the result of a difference in stage of ossification. Proportions of the coracoid plate differ—the procoracoid area being more prominent in *Archeria*, the subglenoid coracoid area being broader in our amphibian. The posterior expansion of the coracoid is unusual for primitive amphibians. Perhaps this fact plus the size and orientation of the glenoid surface indicates a forelimb capable of strong, paddling motions and thus another aquatic feature correlating with the "unfinished" surface of the glenoid.

So little is known of postcranial skeletons of embolomeres (and other Paleozoic amphibia generally) that the characters of our specimen are difficult to assess in detail. In all probability, the amphibian represented was long bodied, aquatic, with well-developed limbs. The presence of an aquatic amphibian in the Garnett fauna strengthens the opinion (Peabody, 1952, p. 40) that a fresh water stream emptied into the marginal, marine lagoon, and that rafting accounts for the rich association of terrestrial with marine organisms.

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STRATIGRAPHICAL AND GEOGRAPHICAL DISTRIBUTION OF THE NAMED SPECIES OF THE TRILOBITE SUPERFAMILY LICHACEA

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ABSTRACT—All named species and subspecies referable to the trilobite superfamily Lichacea are listed, and their general stratigraphical and geographical occurrence recorded. Homonyms and synonyms are listed, together with notes on certain subjective synonyms.

INTRODUCTION

THIS revision of Phleger's (1937) list of species is based upon the classification recently outlined by the author (1957) and submitted to the *Treatise on Invertebrate Paleontology*. The systems have been subdivided into Lower, Middle and Upper in accordance with the correlation charts published by the Geological Society of America (Twenhofel, et al., 1954; Swartz, et al., 1942; Cooper, et al., 1942).

Much of the work has been dependent on the assistance most readily offered by many individuals; in particular, I should like to thank the following for information and for the loan of specimens: Mr. A. G. Brighton, Sedgwick Museum, Cambridge (SM); Dr. W. T. Dean, British Museum (Natural History), London (BM); Professor H. K. Erben, Bonn University; Mr. J. M. Edmonds, Oxford University; Mr. H. O. Fletcher, Australian Museum, Sydney; Dr. M. A. Fritz, Royal Ontario Museum of Palaeontology; Professor T. N. George and Dr. E. D. Currie, Hunterian Museum, Glasgow (HM); Dr. V. Jaanusson, Paleontological Institute, Uppsala University; Mr. G. Murphy, formerly of the Geological Survey of Ireland, Dublin; Fil. Lic. H. Mutvei, Palaeozoological Dept., Swedish Museum of Natural History, Stockholm (RS); Dr. G. Regnéll, Paleontological Institution, Lund University; Mr. J. D. D. Smith, Geological Survey and Museum, London; Dr. J. T. Temple, Birkbeck College, London; Professor H. B. Whittington, Harvard University, Cambridge, Mass. (MCZ); Dr. A. E. Wilson, Geological Survey of Canada, Ottawa; Mr. R. B. Wilson, Geological Survey of Great Britain (Scottish Office) (GSE). The initials following the name of an institution are those used subsequently in referring to particular specimens. I am indebted to Professor H. B. Whittington for the photographs forming figures 1,2, and 6, and to the official photographer at the British Museum (Natural History) for those forming figures 19 and 20.

PRIMARY HOMONYM

Lichas aranea Holzapfel, 1895 [*non Lichas araneus* Lindström, 1885] renamed *araneiformis* Tripp, 1957 (I.C.Z.N. pending).

SECONDARY HOMONYMS

Lichas armatus Hall, 1861 [*non Lichas armatus* (Goldfuss, 1839)] renamed *Lichas eriopis* Hall, 1863.

Lichas canadensis Billings, 1866 [*non Lichas canadensis* (Logan, 1846)] renamed *Amphilichas? anticostiensis* Northrop, 1939 (see p. 578).

Amphilichas obtusicaudatus Troedsson, 1928, here referred to *Hemiarges* [*non Hemiarges anglicus obtusicaudatus* (Reed, 1903)] and considered a subjective synonym of *Hemiarges warburgae* Troedsson, 1928 (see p. 580).

Trimerolichas warburgae Phleger, 1937; here referred to *Platylichas* [*non Platylichas warburgae* Thorslund, 1930] and considered possibly synonymous with *Platylichas halli* (Foerste, 1888) (see p. 580).

NOTES ON CERTAIN JUNIOR SUBJECTIVE SYNONYMS

1. *Autoloxolichas reedi* Phleger, 1937. Comparison of photographs of the holotype (Pl. 85, figs. 1,2) with a fine cranidium of *Uralichas avus* in the British Museum (Nat. Hist.) (I.15228) demonstrates that the two species are synonymous, a conclusion apparently in accordance with the views of Přibyl (1953, p. 56).

2. *Amphilichas? anticostiensis* Northrop,

TABLE 1.—STRATIGRAPHICAL AND GEOGRAPHICAL DISTRIBUTION OF TRILOBITE SPECIES

Ordovician			Silurian			Devonian				Scandinavia	Estonia	Br. Isles	N. America	Other
L	M	U	L	M	U	L	M	U						
									Superfamily LICHACEA Kobayashi, 1935					
									Family LICHIDAE Hawle & Corda, 1847					
									Subfamily LICHINAE Hawle & Corda, 1847					
x	?								*Metopolichas celorrhin* (Angelin, 1854)	x	x			
x									*M. erici* (Warburg, 1939)	x	x			
x									*M. pachyrrhinus* (Dalman, 1828)	x	x			
x									*M. platyrhinus* (Schmidt, 1907)	x	x			
x									*M. verrucosus verrucosus* (Eichwald, 1842)	x	x			
x									*M. verrucosus circumscriptus* (Schmidt, 1907)		x			
x									*M. coniceps* (Leuchtenberg, 1843)		x			
x									*M. longerostratus* (Schmidt, 1907)		x			
x									*M. pakrianus* (Öpik, 1937)		x			
	x								*M. huebneri* (Eichwald, 1842)		x			
	x								*M. kuckersianus* (Schmidt, 1885)		x			
	x								*M. squamulosus* (Öpik, 1937)		x			
	x								*M. wimani* Öpik, 1925		x			
	?								*M. ? applanatus* (Kummerow, 1927)					Germany (erratics)
	x								*M. patriarchus* (Wyatt-Edgell, 1866)			x		
	x								*M. anderkensis* Weber, 1948					U.S.S.R.
	x								*Uralichas avus* (Barrande, 1872)					Bohemia
	x								*U. incola* (Barrande, 1872)					Bohemia
	x								*U. heberti* (Rouault, 1849)					France and Portugal
	x								*U. ribeiroi* (Delgado, 1892)					Portugal and France
	x								*U. ? hispanicus* (Verneuil & Barrande, 1855)					Spain
	x								*Leiolichas illaenoides* (Nieszkowski, 1857)	x	x			Germany (erratics)
		x							*L. gageli* (Pompecki, 1890)					Germany (erratics)
		x							*Lichas affinis* Angelin, 1854	x				
		x							*L. laciniatus* (Wahlenberg, 1821)	x				
		x							*L. keisleyensis* Reed, 1896			x		
		x							*L. subpropinquus* McCoy, 1851			x		
			x						*L. silvestris* Reed, 1925			x		
			x	x					*L. ferrisi* (Weller, 1907)				x	
				x					*L. latifrons* Angelin, 1854	x				
				x					*L. ? araneus* Lindström, 1885	x				Germany (erratics)
				x					*L. ? gothlandicus* Angelin, 1854	x	?			
				x					*L. ? palifer* Lindström, 1885	x				
				x					*L. breviceps breviceps* Hall, 1853				x	
			x	x					*L. breviceps clintonensis* Foerste, 1895				x	
				x					*L. pugnax* Winchell & Marcy, 1865				x	
		x							*Dicranopeltis polytoma* (Angelin, 1854)	x				
		x							*D. bifurcata* (Reed, 1896)			x		
				x					*D. triqueira* (Lindström, 1885)	x				
				x					*D. lindstroemi* (Pompecki, 1890)					Germany (erratics)
				x					*D. salteri* (Fletcher, 1850)	?		x		
				x					*D. woodwardi* (Reed, 1903)			x		
				x					*D. arkansana* (Van Ingen, 1901)				x	
				x					*D. canadensis* (Logan, 1846)				x	
				x					*D. decipiens* (Winchell & Marcy, 1865)				x	
				x					*D. fragosa* Phleger, 1937				x	
				x					*D. greeni* Mason, 1934				x	
				x					*D. ?* nasuta* Weller, 1907				x	
				x					*D. norrisiensis* Shrock & Twenhofel, 1939				x	
				x					*D. telleri* Weller, 1907				x	
				x					*D. reporyjensis* (Phleger, 1937)					Bohemia
				x	x				*D. scabra* (Beyrich, 1845)					Bohemia
			x						*Arclinurus arenaceus* (Twenhofel, 1928)				x	
				x					*A. concinnus* (Angelin, 1854)	x				
				x					*A. marginatus* (Lindström, 1885)	x				
				x					*A. norvegicus* (Angelin, 1854)	x				
				x					*A. ornatus* (Angelin, 1854)	x	x			
				x					*A. plicatus* (Lindström, 1885)	x				
				x					*A. visbyensis* (Lindström, 1885)	x				
				x					*A. constrictus* (Whittard, 1938)			x		
				x					*A. anamosa* Walter, 1925				x	
				x					*A. bolloni* (Bigsby, 1825)				x	
				x					*A. chicagoensis* Weller, 1907				x	
				x					*A. clairensis* Thomas, 1929				x	
				x					*A. inexpectans* (Phleger, 1937)				x	
				x					*A. iowensis* (Walter, 1925)				x	

* Thanks to the courtesy of Professor H. B. Whittington, I have recently been able to study photographs of the specimen described as *Trochurus nasutus* (Weller) by Raymond, 1916. Despite the absence of the depressed area at the base of the median glabellar lobe, it does seem possible that this species shuld be referred to *Trochurus*, and that the genus *Makromuktis* Phleger, of which it is the type species, is a synonym of *Trochurus* and not of *Dicranopeltis*; however, no decision can be reached until the holotype has been reexamined.

TABLE 1 (*Continued*)

Ordovician			Silurian			Devonian				Scandinavia	Estonia	Br. Isles	N. America	Other
L	M	U	L	M	U	L	M	U						
				x					*A. nereus* (Hall, 1863)				x	
				x					*A. obvius* (Hall, 1870)				x	
				x					*A. occidentalis* (Hall, 1863)				x	
				x					*A. shallopensis* (Twenhofel, 1928)				x	
				x					*A. thompsoni* Miller & Unklesbay, 1944				x	
						x			*Gaspelichas forillonia* (Clarke, 1907)				x	
						x			*Echinolichas ? bellamicus* (Clarke, 1907)				x	
						x			*E. bigsbyi* (Hall, 1859)				x	
						x			*E. ? pustulosus* (Hall, 1859)				x	
							x		*E. eriopis* (Hall, 1863)				x	
							x		*E. hispidus* (Hall & Clarke, 1888)				x	
							x		*E. hylaeus* (Hall & Clarke, 1888)				x	
							x		*Ceratolichas dracon* (Hall & Clarke, 1888)				x	
							x		*C. gryps* (Hall & Clarke, 1888)				x	
							x		*Teraiaspis grandis* (Hall, 1861)				x	
									LICHINAE INCERTI GENERIS					
x									*Lichas klouceki* Ružička, 1926					Bohemia
x									*L. praecursor* Holub, 1911					Bohemia
	x								*L. sinensis* Sun, 1931					China
									Subfamily HOMOLICHINAE Phleger, 1936					
x									*Conolichas ? oelandicus* (Angelin, 1854)	x				
	x								*C. deflexus* (Angelin, 1854)	x	x			Germany (erratics)
	x								*C. peri* Warburg, 1939	x	x			
	x								*C. sjoegreni* Warburg, 1939	x				
	x								*C. aequilobus* (Steinhardt, 1874)		x			Germany (erratics)
	x								*C. monticulosus* (Öpik, 1937)		x			
	x								*C. pahleni* (Schmidt, 1885)		x			?Germany (erratics)
	x								*C. schmidti* Dames, 1877		x			
	x								*C. triconicus* Dames, 1877		x			Germany (erratics)
	x								*C. branconis* (Pompecki, 1890)					Germany (erratics)
	x								*C. melmerbiensis* (Reed, 1907)			x		
		x							*C. angustus* (Beyrich, 1846)	?	x			Germany (erratics)
		x							*C. eichwaldi* (Nieszkowski, 1857)	x	x			Germany (erratics)
	x								*Hoplolichas conicotuberculatus* (Nieszkowski, 1859)	x	x			Germany (erratics)
	x								*H. curvifrons* (Warburg, 1939)	x	?			
	x								*H. dissidens* (Beyrich, 1845)	x	x			Germany (erratics)
	x								*H. proboscideus proboscideus* Dames, 1877	x				Germany (erratics)
	x								*H. proboscideus elongatus* Warburg, 1939	x				
	x								*H. furcifer* (Schmidt, 1885)		x			
	x								*H. ? longispinus* (Schmidt, 1885)		x			Germany (erratics)
	x								*H. plautini* (Schmidt, 1885)		x			?Germany (erratics)
	x								*H. medius* (Pompecki, 1890)					Germany (erratics)
	x								*Platylichas boltniensis* (Wiman, 1908)	x				
	x								*P. dalmani* Warburg, 1939	x				
	x								*P. lingua* Warburg, 1939	x				
	x								*P. latus* (Törnquist, 1884)	x				?Germany (erratics)
	x								*P. nasutus* (Wigand, 1888)	x				Germany (erratics)
	x								*P. robustus* Warburg, 1925	x				
	x								*P. validus* (Linnarsson, 1869)	x				
	x								*P. warburgae* Thorslund, 1930	x				
	x								*P. wegelini* Warburg, 1925	x				
	x								*P. fossulatus* Öpik, 1937		x			
	x								*P. sanctaemathiasae* (Schmidt, 1885)		x			
	x								*P. inconsuetus* Raymond, 1925				x	
	x	x							*P. laxatus* (McCoy, 1846)	x		x		Belgium
		x							*P. angulatus* Warburg, 1925	x				
		x							*P. cicatricosus* (Lovén, 1846)	x				
		x							*P. mastocephalus* (Öpik, 1937)	x	x			
		x							*P. docens* (Schmidt, 1885)		x			
		x							*P. hamatus* (Schmidt, 1885)		x			
		x							*P. margaritifer* (Nieszkowski, 1857)		x			
		x							*P. vultuosus* Öpik, 1937		x			
		x							*P. crescenticus* (Reed, 1935)			x		
		x							*P. thraivensis* (Reed, 1935)			x		
		x							*P. halli* (Foerste, 1888)				x	
		x							*P. miseneri* Foerste, 1920				x	
		x							*P. parvus* Cooper & Kindle, 1936				x	
		x							*P. gracilis* (Kummerow, 1927)					Germany (erratics)
			x						*P. scoticus* (Reed, 1906)			x		
				x					*P. grayi* (Fletcher, 1850)		x	x		
									Subfamily TETRALICHINAE Phleger, 1936					
	x								*Lyralichas bronnikovi* (Weber, 1932)					Turkestan
	x								*Amphilichas atavus* Warburg, 1925	x				
	x								*A. hexadactylus* (Nieszkowski, 1857)		x			

TABLE 1 (*Continued*)

Ordovician			Silurian			Devonian							
L	M	U	L	M	U	L	M	U		Scandinavia	Estonia	Br. Isles	N. America	Other
	x								*A. ardmillanensis* (Reed, 1914)			x		
	x								*A. declivis* Tripp, 1954			x		
	x								*A. hibernicus* (Portlock, 1843)			x		
	x								*A. planus* Tripp, 1954			x		
	x								*A. transversus* (Reed, 1926)			x		
	x								*A. antiquarius* (Bradley, 1930)				x	
	x								*A. conifrons* Ruedemann, 1916				x	
	x								*A. cornutus* (Clarke, 1894)				x	
	x								*A. cucullus cucullus* (Meek & Worthen, 1865)				x	
	x								*A. cucullus ottawaensis* (Foerste, 1919)				x	
	x								*A. jukesi* (Billings, 1865)				x	
	x								*A. minganensis* (Billings, 1865)				x	
	x								*A. narrawayi* (Foerste, 1920)				x	
	x								*A. pandus* Evitt, 1951				x	
	x								*A. prominulus* (Raymond, 1925)				x	
	x								*A. pulcher* Teichert, 1937				x	(Greenland)
	x								*A. robbinsi* (Ulrich, 1892)				x	
	x								*A. staebleri* Hussey, 1941				x	
	x								*A. subdisjunctus* (Bradley, 1930)				x	
	x								*A. trentonensis* (Conrad, 1842)				x	
	x								*A. welleri* (Foerste, 1920)				x	
	x	†							*A. karakensis* Weber, 1948					U.S.S.R.
	x								*A. punctatus* (Weber, 1948)					U.S.S.R.
	x								*A. tibetanus* (Salter, 1865)					N. Himalaya
	x								*A. ? browni* (Sun, 1931)					China
		x							*A. dalecarlicus* (Angelin, 1854)	x	x			
		x							*A. latifrons* Warburg, 1925	x				
		x							*A. lineatus* (Angelin, 1854)	x	x			
		x							*A. parvulus* Warburg, 1925	x				
		x							*A. periformis* Warburg, 1925	x				
		x							*A. wahlenbergi* Warburg, 1925	x				
		x							*A. holmi* (Schmidt, 1885)		x			Germany (erratics)
		x							*A. laevis* (Eichwald, 1857)		x			
		x							*A. marchica* (Kummerow, 1927)					Germany (erratics)
		x							*A. bicornis* (Ulrich, 1892)				x	
		x							*A. borealis* Twenhofel, 1928				x	
		x							*A. clermontensis* Slocom, 1913				x	
		x							*A. harrisi* (Miller, 1878)				x	
		x							*A. rhinoceros* Slocom, 1913				x	
		x							*A. rubrus* Cooper & Kindle, 1936				x	
		x							*A. shideleri* (Foerste, 1919)				x	
		x							*A. batchaticus* Weber, 1928					U.S.S.R.
		x							*A. sniatkovi* (Weber, 1924)					U.S.S.R.
									Subfamily CERATARGINAE Tripp, 1957					
	x								*Hemiarges angustifrons* Tripp, 1954			x		
	x								*H. antelucanus* Tripp, 1954			x		
	x								*H. aeolus* Sinclair, 1944				x	
	x								*H. bartoni* Raymond, 1925				x	
	x								*H. leviculus* Bradley, 1930				x	
	x	x							*H. paulianus* (Clarke, 1894)				x	(Greenland)
	x								*H. tuberculatus* (Weller, 1903)				x	
		x							*H. memorans* Öpik, 1937		x			
		x							*H. wesenbergensis* (Schmidt, 1885)		x			
		x							*H. geikiei* (Nicholson & Etheridge, 1879)			x		
		x							*H. maccullochi* (Reed, 1914)			x		
		x							*H. warburgae* Troedsson, 1928				x	(Greenland)
			x						*H. serus* (Reed, 1935)			x		
				x					*H. gibbus* (Angelin, 1853)	x				Germany (erratics)
				x					*H. illaeniformis* (Wigand, 1888)					Germany (erratics)
				x					*H. bucklandi* (Milne Edwards, 1840)			x		
				x					*H. maia* Reed, 1920			x		
				x					*H. scutalis* (Salter, 1873)			x		
				x					*H. ptyonurus* (Hall & Clarke, 1888)				x	
				x	x				*H. ambiguus* (Barrande, 1846)					Bohemia
					x				*H. heteroclytus* Barrande, 1846					Bohemia
		x							*Trochurus loernquisti* (Gürich, 1901)	x				
				x					*T. bulbosus* Phleger, 1937				x	
				x					*T. byrnesanus* (Miller & Gurley, 1893)				x	
				x					*T. depauperatus* (Van Ingen, 1901)				x	
				x					*T. phlyctainodes* (Green, 1837)				x	
				x					*T. speciosus* Beyrich, 1845					Bohemia
		x							*Dicranogmus aequalis* (Törnquist, 1884)	x				
			x						*D. bartonensis* Fletcher, 1950					Australia
					x				*D. simplex* (Barrande, 1846)					Bohemia

† From the Karakan horizon, regarded as Lower Ordovician by Weber, and correlated with the Arenig. However, *Cybele planifrons* Weber and *Sphaerocoryphe* sp. are recorded from this horizon, and indicate a Middle Ordovician age.

TABLE 1 (*Continued*)

Ordovician			Silurian			Devonian				Scandinavia	Estonia	Br. Isles	N. America	Other
L	M	U	L	M	U	L	M	U	
				x					*Acanthopyge pusilla* (Angelin, 1854)	x				
				x					*A. hirsuta hirsuta* (Fletcher, 1850)			x		
				x					*A. hirsuta tuberculata* (Reed, 1903)			x		
					x				*A. pragensis* (Bouček, 1933)					Bohemia
					x				*A. altirhachis* (Chernysheva, 1951)					U.S.S.R.
						x			*A. consanguinea* (Clarke, 1894)				x	
						x			*A. beryllifera* (Richter, R. 1909)					Germany
						x			*A. hexapteryx* (Přibyl and Erben, 1952)					Germany
						x			*A. permarginata* (Přibyl and Erben, 1952)					Germany
						x			*A. sexlobata* (Roemer, 1855)					Germany
						x			*A. branikensis* (Barrande, 1872)					Bohemia
						x			*A. nitidula* (Barrande, 1872)					Bohemia
						x			*A. parvula parvula* (Novák, 1890)					Bohemia, ?Germany
						x			*A. parvula convexa* (Chernysheva, 1951)					U.S.S.R.
						x			*A. australis* (McCoy, 1876)					Australia
						x			*A. ? sinuata* (Ratte, 1886)					Australia
							x		*A. devoniana* (Whidborne, 1889)			x		
							x		*A. contusa* (Hall & Clarke, 1888)				x	
							x		*A. meridionalis* (Frech, 1887)					France
							x		*A. decheni* (Holzapfel, 1895)					Germany
							x		*A. granulosa* (Roemer, 1852)					Germany
							x		*A. maureri* (Novák, 1890)					Germany
							x		*A. mephisto* (Richter, R. and E., 1917)					Germany
							x		*A. devonica* (Přibyl & Erben, 1952)					Bohemia
							x		*A. haueri* (Barrande, 1846)					Bohemia, Germany
							x		*A. ? plana* (Weber, 1932)					U.S.S.R.
							x		*A. sibirica* (Chernysheva, 1951)					U.S.S.R.
							x		*A. bifida* Edgell, 1955					Australia
							x		*A. balliviani* (Kozlowski, 1923)					Bolivia
							x		*Eifliarges caudimirus* (Richter, R. and E., 1917)					Germany
							x		*Radiolichas araneiformis* Tripp, 1957					Germany
							x		*Akantharges gourdoni* (Barrois, 1886)					France
							x		*Ceratarges armatus armatus* (Goldfuss, 1839)					Europe
							x		*C. armatus berolinensis* Richter, 1909					Europe
								x	*Craspedarges wilcanniae* Gürich, 1901					Australia
									CERATARGINAE INCERTI GENERIS					
						?	?		*Lichas radugini* Weber, 1949					U.S.S.R.
									Family LICHAKEPHALIDAE Tripp, 1957					
x									*Lichakephalus erbeni* Sdzuy, 1955					Germany
									NOMINA DUBIA					
									Trilobites scaber Boeck, 1838	x				
									Lichas depressus Angelin, 1854	x				
									L. planifrons Angelin, 1854	x				
									L. eichwaldi kaiserl., Hoffman, 1858		x			
									L. sexpunctatus Hoffman, 1858		x			
									NOMINA NUDA					
	x								*Lichas giganteus* Holub *in* Klouček, 1917					Bohemia
	x								*Amphilichas inaequalis* Raymond *in* Delo, 1934				x	
				x					*Lichas hendersoni* Lamont, 1943			x		
				x					*Lichas (Pseudartabas) vafer*‡ Lamont, 1943			x		

‡ Probably not a lichid, according to Dr. A. Lamont, 1956 (*in litt.*)

1939. The pygidium from the Jupiter Formation of Anticosti Island which was named *Lichas canadensis* by Billings (1866, p. 65, fig. 22; see Twenhofel, 1928, p. 327, pl. lvii, fig. 9), and renamed *Amphilichas? anticostiensis* by Northrop (1939, p. 235), should be referred to the genus *Arctinurus*. The cranidium from the same horizon and locality which was described as *Amphilichas shallopensis* by Twenhofel (1928, p. 328, pl. lvii, fig. 9) possesses faint occipital lobes, and should be attributed to *Arctinurus* also. The cranidium and pygidium are considered conspecific, pending evidence to the contrary.

3. *Lichas pumila* McCoy, 1846. Warburg (1939, p. 118) omitted *L. pumila* from the synonymy of *P. laxatus*. The type specimen is lost, but the study of specimens recently collected from Carrickadaggan, the type locality, and Ballygarvan Bridge, the type locality of *Platylichas laxatus* (Pl. 85, figs. 3,4), indicates that the two species are identical, although the range of variation is great at both localities.

4. *Lichas nodulosus* Salter *in* McCoy,

TABLE 2.—SUBJECTIVE SYNONYMS IN LICHACEAN TRILOBITES

Junior synonyms		Revised determinations	Authority for synonyms
Lichas macrocephala Eichwald, 1860	? =	*Metopolichas celorrhin* (Angelin, 1854)	Warburg, 1939, p. 24.
L. convexus Angelin, 1854	=	*Metopolichas verrucosus* (Eichwald, 1842)	Warburg, 1939, p. 17.
L. inexpectatus Schmidt, 1907	=	*M. kuckersianus* (Schmidt, 1885)	Öpik, 1930, p. 26.
Autoloxolichas reedi Phleger, 1937	=	*Uralichas avus* (Barrande, 1872)	Note 1.
Lichas conformis Angelin, 1854	=	*Lichas laciniatus* (Wahlenberg, 1821)	Warburg, 1939, p. 15.
L. elegans Törnquist, 1884	=	*Dicranopeltis polytoma* (Angelin, 1854)	Warburg, 1939, p. 134.
L. laticeps Angelin, 1854	=	*D. salteri* (Fletcher, 1850)	Warburg, 1939, p. 108.
Dicranopeltoides ? logani Northrop, 1939	† =	*D. canadensis* (Logan, 1846)	Kindle, 1945, p. 530.
Lichas emarginatus Hall, 1879	=	*D. decipiens* (Winchell & Marcy, 1865)	Weller, 1907, p. 198.
L. propinqua Barrande, 1846	=	*D. scabra* (Beyrich, 1845)	Barrande, 1852, p. 596.
Dicranopeltis granulosa Hawle & Corda, 1847	=	*D. scabra* (Beyrich, 1845)	Barrande, 1852, p. 596.
D. aspera Hawle & Corda, 1847	=	*D. scabra* (Beyrich, 1845)	Barrande, 1852, p. 596.
Amphilichas? anticostiensis Northrop, 1939	† =	*Arctinurus shallopensis* (Twenhofel, 1928)	Note 2.
Lichas superbus Billings, 1875	=	*Terataspis grandis* (Hall, 1861)	Hall & Clarke, 1888, p. 73.
L. platyura Nieszkowski, 1857	=	*Conolichas deflexus* (Angelin, 1854)	Warburg, 1939, p. 52.
L. velata Steinhardt, 1874	=	*C. deflexus* (Angelin, 1854)	Warburg, 1939, p. 52.
L. tricuspidata Beyrich, 1846	=	*Hoplolichas dissidens* (Beyrich, 1845)	Warburg, 1939, p. 75.
L. arenswaldi Boll, 1858	=	*H. dissidens* (Beyrich, 1845)	Warburg, 1939, p. 75.
L. quadricornis Steinhardt, 1874	=	*Hoplolichas dissidens* (Beyrich, 1845)	Warburg, 1939, p. 75.
L. (Platylichas) westergårdi Kummerow, 1927	? =	*Platylichas latus* (Törnquist, 1884)	Warburg, 1939, p. 108.
L. laxatus dilatata Törnquist, 1884	=	*P. latus* (Törnquist, 1884)	Warburg, 1939, p. 108.
L. pumila McCoy, 1846	=	*Platylichas laxatus* (McCoy, 1846)	Note 3.
L. nodulosus Salter *in* McCoy, 1851	=	*P. laxatus* (McCoy, 1846)	Note 4.
L. aculeatus Angelin, 1854	=	*P. laxatus* (McCoy, 1846)	Warburg, 1939, p. 118.
L. sexspinus Angelin, 1854	=	*P. laxatus* (McCoy, 1846)	Warburg, 1939, p. 118.
L. segmentatus Linnarsson, 1866	=	*P. laxatus* (McCoy, 1846)	Warburg, 1939, p. 118.
L. (Platylichas) vicinus Reed, 1935	† =	*P. crescenticus* (Reed, 1935)	Note 5.
L. (Metopolichas?) congruens Reed, 1935	=	*P. thraivensis* (Reed, 1935)	Note 6.
L. faberi Miller, 1889	=	*P. halli* (Foerste, 1888)	Clarke, 1894, p. 754.
Trimerolichas warburgae Phleger, 1937	? =	*P. halli* (Foerste, 1888)	Note 7.
Lichas barrandei Fletcher, 1850	† =	*P. grayi* (Fletcher, 1850)	Note 8.
L. rotundifrons Angelin, 1854	=	*P. grayi* (Fletcher, 1850)	(Westergård, 1910, p. 33. (Note 9.
L. bulbiceps Salter, 1873	=	*P. grayi* (Fletcher, 1850)	Note 10.
L. (Acrolichas) tenuilobatus Reed, 1944	=	*Amphilichas ardmillanensis* (Reed, 1914)	Note 11.
Nuttainia obscura Portlock, 1843	† =	*A. hibernicus* (Portlock, 1843)	Reed, 1952, p. 119.
Lichas (Paralichas) kildarensis Reed, 1902	=	*A. hibernicus* (Portlock, 1843)	Reed, 1906, p. 106.
L. champlainensis Whitfield, 1886	† =	*A. minganensis* (Billings, 1865)	Raymond, 1910, p. 232.
Acrolichas aspratilis Bradley, 1930	? =	*Amphilichas welleri* (Foerste, 1920)	Bradley, 1930, p. 266.
Lichas brevilobatus Törnquist, 1884	=	*A. lineatus* (Angelin, 1854)	Warburg, 1939, p. 140.
L. (Hemiarges) morator Reed, 1935	=	*Hemiarges geikiei* (Nicholson & Etheridge, 1879)	Note 12.
Amphilichas obtusicaudatus Troedsson, 1928	† =	*H. warburgae* (Troedsson, 1928)	Note 13.
Lichas (Corydocephalus) scutalis bella Reed, 1935	† =	*H. serus* (Reed, 1935)	Note 14.
Arges anglicus Beyrich, 1846	=	*H. bucklandi* (Milne Edwards, 1840)	Note 15.
Lichas (Corydocephalus) anglicus wenlockensis Reed, 1903	=	*H. bucklandi* (Milne Edwards, 1840)	Note 16.
Lichas (Corydocephalus) anglicus obtusicaudatus Reed, 1903	=	*H. bucklandi* (Milne Edwards, 1840)	Note 16.
L. hanoverensis Miller & Gurley, 1893	=	*Trochurus phlyctainodes* (Green, 1837)	Weller, 1907, p. 193.
L. palmata Barrande, 1846	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
Corydocephalus flabellatus Hawle & Corda, 1847	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
C. verrucosus Hawle & Corda, 1847	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
C. interjectus Hawle & Corda, 1847	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
C. propinquus Hawle & Corda, 1847	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
Acanthopyge pulchra Hawle & Corda, 1847	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
A. speciosa Hawle & Corda, 1847	=	*T. speciosus* Beyrich, 1845	Barrande, 1852, p. 599.
Dicranogmus pustulatus Hawle & Corda, 1847	=	*Dicranogmus simplex* (Barrande, 1846)	Barrande, 1852, p. 608.
Lichas parvus Barrande, 1846	=	*Acanthopyge haueri* (Barrande, 1846)	Barrande, 1852, p. 604.
Acanthopyge leuchtenbergi Hawle & Corda, 1847	=	*A. haueri* (Barrande, 1846)	Barrande, 1852, p. 604.
Lichas armata geesiana Richter, 1909	=	*Ceratarges armatus armatus* Goldfuss, 1849	Richter, 1956, *in litt.*

† Denotes species the synonymy of which depends on the unverified association of different parts of the exoskeleton.

1851. A rubber latex cast from the external mould of the holotype is figured (Pl. 85, fig. 5); this type of pygidium is not uncommon in the Lower Longvillian beds of North Wales, and associated cranidia are not specifically distinguishable from *Platylichas laxatus*. However, when more complete knowledge is available, it is likely that it will prove possible to recognize *nodulosus* as one of several subspecies of *P. laxatus*.

5. *Lichas* (*Platylichas*) *vicinus* Reed, 1935. Thoracic segments associated with the holotype pygidium of *P. vicinus* (Reed, 1935, p. 33), and with the cephalon of *P. crescenticus* (Reed, 1935, p. 29) are extremely similar. The two forms, which are from the Starfish Bed, Upper Drummuck, Ladyburn, Ayrshire, are considered synonymous.

6. *Lichas* (*Metopolichas?*) *congruens* Reed, 1935. A dorsal shield in Mr. J. L. Begg's collection (HM A. 3967) (Pl. 85, figs. 7,8) has a cranidium referable to *Platylichas congruens* (Reed, 1935, p. 34) and a pygid-

ium referable to *P. thraivensis* (Reed, 1935, p. 32), showing that these two nominal species are synonymous; the name applied to the pygidium is adopted on the grounds of page priority.

7. *Trimerolichas warburgae* Phleger, 1937. As noted above (p. 16) *Platylichas warburgae* (Phleger, 1937) is a junior secondary homonym; to judge from a photograph of the holotype (Pl. 85, fig. 6), it seems possible that this species is a synonym of *P. halli* (Foerste, 1888) and therefore no replacement name is proposed at present.

8. *Lichas barrandei* Fletcher, 1850. There is only one type of *Platylichas* pygidium associated with the *Platylichas grayi* cranidia in the Wenlock Limestone—that named *L. barrandii* (*recte barrandei*) by Fletcher—and the two nominal species are considered identical.

9. *Lichas rotundifrons* Angelin, 1854. The incomplete cranidium figured by Angelin (pl. xxxvi, figs. 7,7a,7b) is undoubtedly conspecific with a more complete cranidium preserved in the same collection (Pl. 85, figs. 9–11). The latter differs from most specimens of *Platylichas grayi* in that the longitudinal convexity is stronger, the bicomposite lateral lobes are broader at the back, and the ornamentation is sparser, but these differences are not sufficiently marked to distinguish a taxonomic unit.

10. *Lichas bulbiceps* Salter, 1873. *L. bulbiceps* Phill. m.s. was listed by Huxley & Etheridge (1865, p. 5,19), a *nomen nudum*. Salter (1873, p. 37) catalogued a specimen from Mulloch Hill as "*Lichas bulbiceps?* Salter & Phillips (Mem. Geol. Surv. ii, Pt. 1, pl. viii, fig. 8). I am not sure of this being the Dudley one." This passage is accepted as providing a bibliographic reference (Salter *in* Phillips & Salter, 1848, pl. viii, figs. 8,8a) for the nominal species *Lichas bulbiceps*. However, Fletcher (1850, p. 237) had already correctly referred the specimen figured by Salter in 1848 to his *L. grayi*. (It may be noted that this specimen is from Ledbury, not from Malvern, as Fletcher stated, nor from Dudley, as Salter (1873) indicated.)

The cranidium from Keisley (SM A.11908) referred to *L. bulbiceps* Phill. m.s. by Reed (1896, p. 428, pl. xxi, figs. 8,8a,8b) and the pygidium from the same locality (SM A.11910), which Reed named *L. bifurcatus* (1896, p. 431, pl. xxi, fig. 7) should be referred to the one species of *Dicranopeltis*, as Warburg (1925, p. 294) has pointed out. For this species the name *D. bifurcata* (Reed) must be adopted. The hypostome doubtfully referred to this form by Reed (1896, pl. xxi, fig. 9) really belongs to *Platylichas laxatus*.

11. *Lichas* (*Acrolichas*) *tenuilobatus* Reed, 1944. The holotype is figured (Pl. 85, fig. 12); there can be little doubt that this is an immature cranidium of *Amphilichas ardmillanensis* (Reed).

12. *Lichas* (*Hemiarges*) *morator* Reed, 1935. Reed referred only a single specimen to *H. morator* (Pl. 85, fig. 17). Study of the large series of specimens of *H. geikiei* now available in the British Museum (Nat. History) indicates that the holotype of *H. morator* is no more than the narrow form of *Hemiarges geikiei*.

13. *Amphilichas obtusicaudatus* Troedsson, 1928. The pygidium on which *A. obtusicaudatus* was founded must be attributed to *Hemiarges* on account of the post-axial ridge and large third pleurae. Cranidia of two species of *Hemiarges* occur associated with this pygidium—*H. paulianus* (Clarke) and *H. warburgae* (Troedsson). The pygidium of *H. paulianus* is quite different from the one under discussion; *H. obtusicaudatus* is therefore provisionally regarded as the pygidium of *H. warburgae*.

14. *Lichas* (*Corydocephalus*) *scutalis bella* Reed, 1935. In 1906 Reed referred certain cranidia and pygidia from Mulloch Hill and Newlands to *L. scutalis*, but in 1935 he referred the pygidia from Mulloch Hill to a new subspecies, *bella*. In the same paper he founded a new species, *L.* (*Hemiarges*) *serus* upon a cranidium from Mulloch Hill. There is no significant difference between *L. serus* (Pl. 85, fig. 18) and the cranidia referred by Reed to *L. scutalis* or between the pygidia from Mulloch Hill (Pl. 85, fig. 19) and Newlands (Pl. 85, fig. 20). All the material under discussion appears to belong to the one species of *Hemiarges*, which is quite distinct from *H. scutalis*, and for which the name *H. serus* is adopted.

15. *Arges anglicus* Beyrich, 1846. Milne Edwards (1840, p. 345, pl. xxxiv, fig. 12) founded the species *Peltura bucklandi* on the specimen figured by Brongniart (1822, p. 145, pl. iv, fig. 9) as the "Trilobite de Dud-

ley." McCoy (1851, p. 151) regarded Milne Edwards' figure as unintelligible, and this opinion has been followed by later authors. The specimen illustrated is a ventral view of an incompletely exposed dorsal shield in M. Cartwright's Collection, the whereabouts of which are unknown. The illustration (Pl. 85, fig. 13) is somewhat diagrammatic, but it shows points of sufficient diagnostic importance to identify the species, which is the most abundant lichid at Dudley. The occurrence of a median spine on the margin of the pygidium distinguishes the form from all known British species; the presence of this median spine is also indicated in Milne Edwards' description—"Bouclier abdominal garni de sept pointes marginales"—but Milne Edwards included the short first pair of pleurae of the pygidium with the thorax. Furthermore, the post-axial ridge of the pygidium rules out all other Wenlock species except *Acanthopyge hirsuta* (Fletcher), and it is clear from the absence of the deep notch inside the librigenal spine that the specimen under discussion does not belong to that species. In the writer's opinion, therefore, *P. bucklandi* was founded with an adequate description and illustration, and is unequivocally recognisable.

Beyrich (1846, p. 11, pl. i, fig. 3) erected the species *Arges anglicus* on a cranidium from Dudley; Fletcher (1850, p. 235) correctly placed *A. anglicus* in the synonymy of *L. bucklandi*.

16. *Lichas* (*Corydocephalus*) *anglicus wenlockensis* Reed, 1903, and *Lichas* (*Corydocephalus*) *anglicus obtusicaudatus* Reed, 1903. Reed (1903, p. 3–4, pl. i, figs. 1,2) distinguished three subspecies of *L. anglicus:* the type form, with semicircular pygidium and normally developed third pair of marginal spines; *wenlockensis*, with subquadrate pygidium and an enlarged third pair of marginal spines; *obtusicaudatus*, with subquadrate pygidium and only two (instead of three) supplementary marginal spines between the third pair. I have developed the two syntypes on which Reed based his restoration of *obtusicaudatus* (Pl. 85, figs. 15, 16), and both specimens possess well developed third (median) supplementary spines, as do all other specimens formerly referable to this subspecies that I have been able to study. The subspecies *obtusicaudatus*, therefore, cannot stand. Enlarged third spines occur on semicircular and subquadrate pygidia; consequently the subspecies *wenlockensis* cannot be recognized.

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EXPLANATION OF PLATE 85

FIGS. *1,2*—*Uralichas avus* (Barrande). Dorsal and frontal views of a cranidium, the holotype of *Autoloxolichas reedi* Phleger, ×1. Šárka Beds, Vosek, Bohemia, MCZ 4475 (Schary Collection).

3–5—*Platylichas laxatus* (McCoy). *3*, cranidium, ×3. Carrickadaggan, New Ross, Eire, HM A.3966. *4*, cranidium, ×3. Ballygarvan Bridge, New Ross, Eire (the type locality), HM A.3965. *5*, rubber latex cast from external mould of pygidium, holotype of *Lichas nodulosus* Salter in McCoy, ×3. Pont-y-glyn, Denbighshire, Wales, SM A.41346a.

6—*Platylichas halli* (Foerste)? Cranidium, holotype of *Trimerolichas warburgae* Phleger, ×2. Cincinnatian, Cincinnati district, Ohio, MCZ 4473.

7,8—*Platylichas congruens* (Reed). Oblique anterior and dorsal views of a dorsal shield, pygidium formerly referable to *Lichas* (*Platylichas*) *thraivensis* Reed, ×1. Starfish Bed, Upper Drummuck Group, Ladyburn, Ayrshire, Scotland, HM A.3967 (Begg Collection).

9–11—*Platylichas grayi* (Fletcher). *9,10*, dorsal and lateral views of cranidium, ×3. Gotlandian, Visby, Gotland, RS Ar.2448. *11*, cranidium, the holotype of *Lichas rotundifrons* Angelin, ×3. Horizon and locality as figs. *9,10*, RS Ar.2460.

12—*Amphilichas ardmillanensis* (Reed). Cranidium, the holotype of *Lichas* (*Acrolichas*) *tenuilobatus* Reed, ×9. Balclatchie Group, Balclatchie, Ayrshire, Scotland, HM A.3647 (Begg Collection).

13–16—*Hemiarges bucklandi* (Milne Edwards). *13*, reproduction of Milne Edwards' (1840, pl. xxxiv, fig. 12) illustration of *Peltura bucklandi*. *14*, ventral view of exoskeleton, ×4. Wenlock Limestone, Dudley, Worcestershire, England, BM In.44738. *15,16*, pygidia, syntypes of *Lichas* (*Corydocephalus*) *anglicus obtusicaudatus* Reed, developed to show the three supplementary marginal spines, ×6. Horizon and locality as fig. *14*, SM A.10270, A.10271 (Fletcher Collection).

17—*Hemiarges geikiei* (Nicholson and Etheridge). Cranidium, the holotype of *Lichas* (*Hemiarges*) *morator* Reed, ×2. Starfish Bed, Upper Drummuck Group, Ladyburn, Ayrshire, Scotland, GSE 2099b (John Smith Collection).

18–20—*Hemiarges serus* (Reed). *18*, the holotype cranidium, ×8. Mulloch Hill Group, Mulloch Hill (in wood), Ayrshire, Scotland, BM In.36953 (Gray Collection). *19*, pygidium, the holotype of *Lichas* (*Corydocephalus*) *scutalis bella* Reed, ×4. Horizon and locality as fig. *18*, BM In.36955 (Gray Collection). *20*, pygidium, original of Reed, 1906, pl. xiv, fig. 4, ×4. Saugh Hill Group, Newlands, Ayrshire, Scotland, BM In.22724 (Gray Collection).

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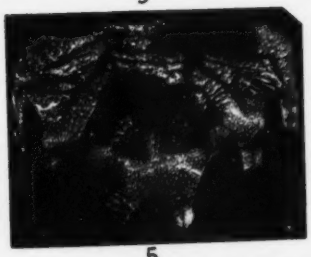
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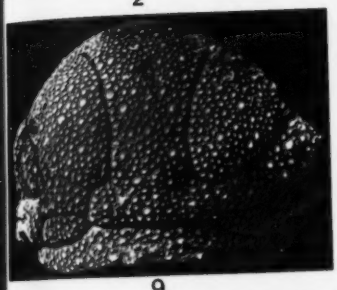
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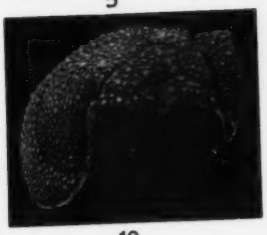
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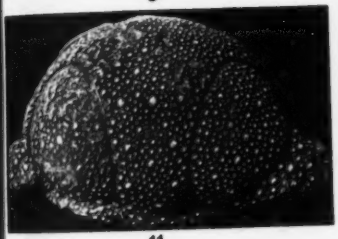
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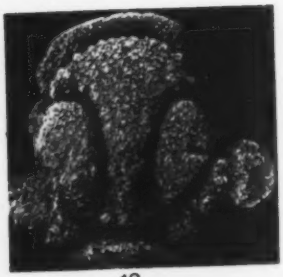
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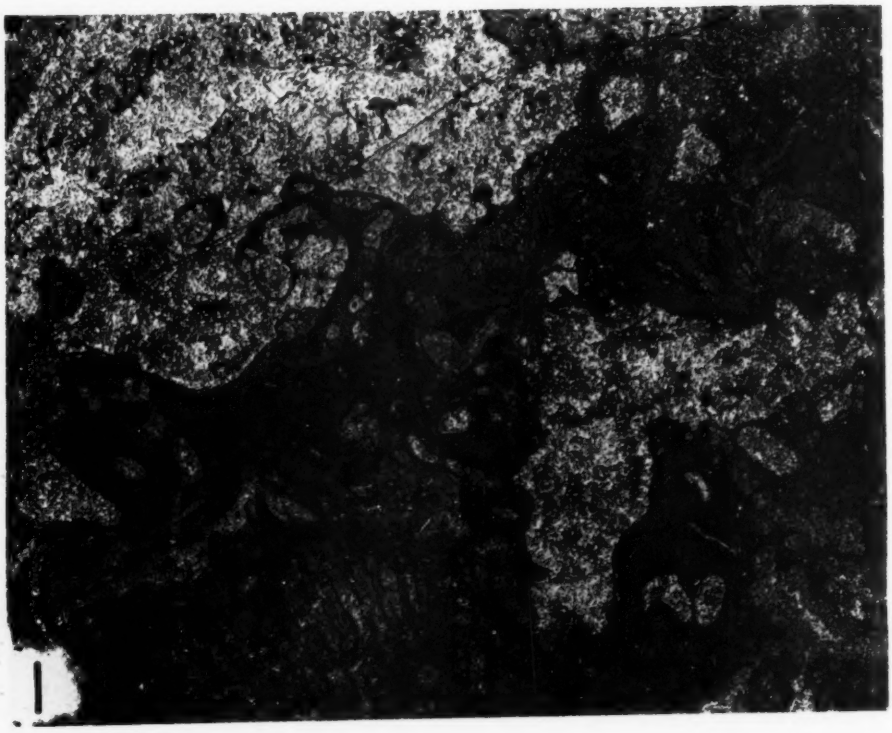

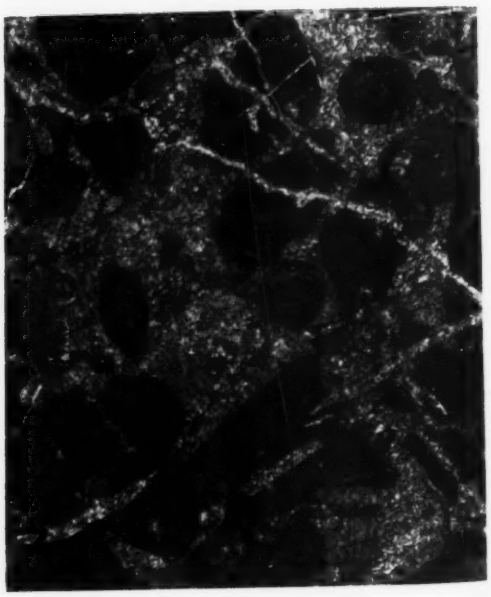

JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 583–586, PL. 86, 3 TEXT-FIGS., MAY 1958

TWO NEW UPPER PALEOZOIC HYDROZOANS

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ABSTRACT—The new hydrozoans, *Nigriporella magna* and *N. minima* are described from upper Paleozoic rocks of the western United States. These fossils are included in the new family, Nigriporellidae. Nigriporellids differ from other hydrozoans in having a very dense, minutely fibrous coenosteum, perforated by chambered zooidal tubes of two diameters.

INTRODUCTION

HYDROZOANS, a minor class of coelenterates, include the common stromatoporoids. Other orders of the class, such as Milleporida, Hydroida, Sphaeractiniida, and Stylasterida, are of interest only where locally abundant. One such abundant occurrence of hydrozoans is in the Permian rocks of Texas and New Mexico, where they constitute an important and distinctive part of the fauna of reefs in the Guadalupe Mountains (Newell et al., 1953). Hydrozoans are considered to be as important in reef formation in Permian rocks as they are in present living reef tracts.

Additional investigation by the writer led to the recognition of the same hydrozoan in most reef tracts from Leonardian to Capitanian ages in the Glass and Chinati Mountains in Texas. Similar hydrozoans are also present elsewhere in the western states in rocks as old as Osagean and as young as upper Permian (*Neoschwagerina*-zone).

SYSTEMATIC PALEONTOLOGY

Class HYDROZOA
Order uncertain
Family NIGRIPORELLIDAE, n. fam.

Description.—Stoloniform or massive, encrusting, calcareous, upper Paleozoic hydrocorallines in which the coenosteum is very finely fibrous, appearing dark-gray to opaque in most thin sections. Zooidal tubes of two sizes connected by a small meandering canal system, tubules chambered in interior part of coenosteum, rarely tabulate. Coenosteum lacks characteristic pillars and astrorhizae of the stromatoporoids.

Taxonomic position.—Taxonomic position of the nigriporellids is not readily apparent for they represent a minor extinct group of organisms. They have structural elements that most closely resemble milleporids and stromatoporoids. Both milleporids and nigriporellids possess differentiated zooidal tubes connected by a meandering canal system. Tubules are subdivided into chambers by perforate partitions in the nigriporellids and by tabulae in milleporids. Although of differing textural density, the coenosteum of both is composed of fibrous calcareous material with relatively well-defined trabeculae.

The latilamellar habit of both nigriporellids and stromatoporoids is well defined and clearly shows similar modes of growth. It is possible that the zooidal tubes of *Nigriporella* are related to astrorhizae of stromatoporoids, but the possibility seems remote. Nigriporellids are not considered, for the present, as belonging in the Stromatoporida

EXPLANATION OF PLATE 86

All figures ×10

FIG. *1*—*Nigriporella magna* n. sp., photomicrograph of cellulose peel of holotype, upper Leonard limestone, Glass Mountains, Texas, locality 927 AMNH, 10979 BYU.

2—*N. minima* n. sp., photomicrograph of holotype thin section, lower Humbug limestone, Wasatch Mountains, Utah, locality 10978 BYU.

3—*N. minima*, photomicrograph of thin section of upper Permian specimen from quarry 4½ miles east of Arlington, Washington locality 10977 BYU, Univ. of Washington 3485.

TEXT-FIG. 1—*Nigriporella magna*. Idealized restored sketch of coenosteum showing probable mode of growth and relationship of zooidal tubes to remainder of colony. Approximately ×10.

because of the strong development of pillars in the latter group.

Superficially, zooidal tubes of *Nigriporella* resemble canals of sponges. Chambered tubules and lack of definite skeletal elements akin to spicules make it impossible to class the genus with sponges. In addition, sponges, in thin sections where *Nigriporella* is present, are commonly intensely recrystallized. In many thin sections, the sponges are obliterated but the nigriporellids have seemingly undergone little change.

Although for the present it seems best not to place the nigriporellids in any of the described orders of hydrozoans, there can be little doubt that they should be included in this class. Nigriporellids are considered as hydrozoans because of their mode of growth, presence of two types of zooidal tubes, and latilamellar structure.

Genus NIGRIPORELLA, n. gen.

Description.—Calcareous coenosteum stoloniform, ramose, or encrusting of variable form but composed of latilaminae which show varying density. Zooidal tubes, gastropores and dactylopores, appear as irregular tubules surrounded by a well-defined dense layer of the coenosteum. Both gastropores and dactylopores are chambered in central portions of the colony. Individual chambers are about as long as the tubes are wide, with each chamber separated from the previous by a partition approximately one-quarter as thick as the tubes are wide. A central opening perforates the partition. Distal ends of zooidal tubes are unchambered.

A minor tubule or canal system is present in most specimens of the genus, and is most apparent in large colonies. Such canals have approximately the diameter of dactylopores. In transverse sections dactylopores and canals are impossible to differentiate, but longitudinal sections show chambering of dactylopores. In central parts of the coenosteum, the canals are commonly filled by dark skeletal material.

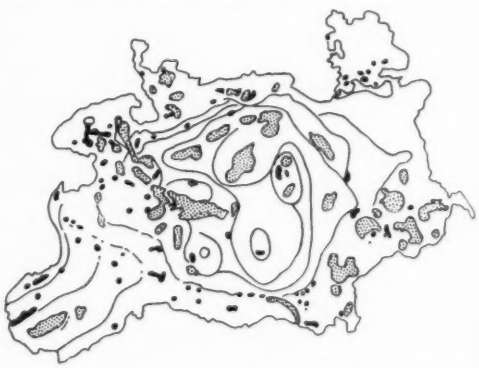
Genotype.—*Nigriporella magna* Rigby.

NIGRIPORELLA MAGNA, n. sp.
Pl. 86, fig. 1; text-figs. 1,2

Undescribed hydrocoralline, Newell, et al., 1953, pl. 17, fig. 3; pl. 18, figs. 1–6.
Undescribed hydrocoralline, Newell, 1955, p. 307, pls. 4,5,6B,7B,8.

Description.—Massive encrusting or ramose coenosteum of variable form, but composed of superimposed laminae defined by differing density of skeletal material. Coenosteum much more dense near upper surface of laminae and in vicinity of zooidal tubes. Dactylopores and gastropores prominent and often connected by minor interconnecting canals. Diameter of gastropores ranges from 0.20 to 0.72 mm. in the holotype and from 0.11 to 0.72 mm. in other specimens of the species. Diameter of dactylopores ranges from 0.12 to 0.19 mm. in the holotype and from 0.04 to 0.20 mm. in other specimens.

Dactylopores are approximately five times as abundant as gastropores, and are seemingly more randomly placed. In large colonies, with diameters over 5 millimeters, gastropores are more common in the center of the mass and dactylopores at the margins of the colony (text-fig. 2).



TEXT-FIG. 2—*Nigriporella magna*. Line drawing (bleached photograph) illustrating distribution of dactylopores (solid black) and gastropores (stippled) in characteristic colony. Thin section from Cibolo limestone, Chinati Mountains, Texas, locality 915 AMNH. ×10.

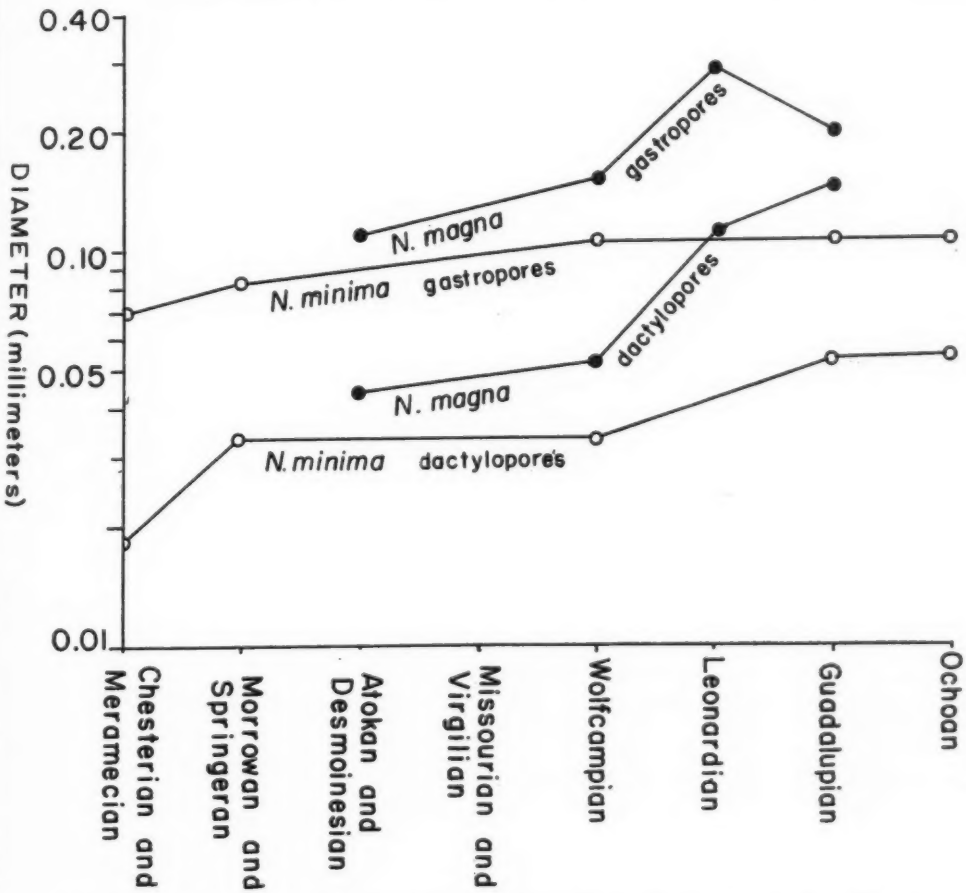
The modal size of both gastropores and dactylopores increases from stratigraphically lower to higher specimens (text-fig. 3). Gastropores average approximately 0.11 mm. in diameter for middle Pennsylvanian forms and 0.29 mm. in diameter for Leonardian forms. Dactylopores average approximately 0.05 mm. in diameter for middle Pennsylvanian forms and 0.11 mm. for Leonardian forms of the species.

Occurrence.—*Nigriporella magna* is common in most massive limestone beds in the Permian rocks of the Glass, Chinati, Apache, and Guadalupe Mountains. It is particularly common in Leonardian and Guadalupian formations. The type specimens are from the lower Leonard formation immediately above the Hess formation, one-quarter of a mile east of Split Tank in the central Glass Mountains, Texas. Locality 927 AMNH, 10979 BYU.

Disposition of types.—Holotype and paratypes are in the Type Collections Repository at Brigham Young University in Provo, Utah.

NIGRIPORELLA MINIMA, n. sp.
Pl. 86, figs. 2,3

Description.—Hemispherical to subhemispherical *Nigriporella* in which the gastropores and dactylopores are small and abundant. Gastropores range from 0.097 to 0.125 mm. in diameter and dactylopores range from 0.017 to 0.086 mm. in diameter



TEXT-FIG. 3—Graph of modal diameter of gastropores and dactylopores of Mississippian to Permian *Nigriporella minima* and *N. magna*.

Colony may form as hemispherical encrustation over various fragments such as crinoid columnals, brachiopod or bryozoan fragments.

Discussion.—*Nigriporella minima* differs from *N. magna* in being consistently smaller and more regular in its growth pattern. Dactylopores and gastropores are much smaller in the former in all specimens, but both show gradual increase in size vertically through the geologic section (text-fig. 3). Gastropores of Mississippian representatives of *N. minima* have a modal diameter of approximately 0.07 mm., which gradually increases until upper Permian forms have a modal diameter of approximately 0.11 mm. Dactylopores of Mississippian representatives of the species have an average modal diameter of 0.018 mm., and increase until upper Permian forms have a diameter of 0.052 mm.

Nigriporella minima characteristically occurs in association with foraminifera. Mississippian forms are commonly associated with various endothyrid foraminifera. Pennsylvanian forms occur with *Millerella*, *Triticites*, *Fusulina*, and other fusulines. Permian representatives of the species occur in beds replete with *Schwagerina*, *Parafusulina*, *Polydiexodina*, and *Neoschwagerina*.

Occurrence.—*Nigriporella minima* occurs in most clastic limestone in the upper Paleozoic section examined by the writer in Utah and Nevada. It is particularly abundant in the Madison, Deseret, Humbug, and Pine Canyon limestones of Mississippian age in central and northern Utah. It is also abundant in the Oquirrh formation of Pennsylvanian and lower Permian ages in central Utah, and time-equivalent formations in eastern Nevada. The species is also common in upper Permian limestone in Washington. Other specimens have been noted, in varying abundance, in Pennsylvanian limestones from Texas and New Mexico. The holotype is from the lower Humbug formation in Provo Rock Canyon, in the central Wasatch Mountains of central Utah. Locality 10978 BYU.

Disposition of types.—Holotype and paratypes are in the Type Collections Repository at Brigham Young University in Provo, Utah.

MODE OF GROWTH

Earliest stages of growth of *Nigriporella* are not now known, but much can be inferred concerning growth of later parts of the colony. Once initiated, tubules extended themselves by first depositing a thin, usually less than 0.001 mm. thick, tube of dense fibrous coenosteum beyond the last level of growth. These extensions probably amounted to approximately the thickness of laminae within the coenosteum, perhaps as much as half a millimeter. Accompanying this extension, less dense coenosteum enveloped the early part of the tubule and enlarged the entire colony. This periodic growth produced the laminae characteristic of the family. Fragments of thin early tubules are scattered throughout the detritus which is commonly associated with the colonies. Small segments, particularly of the tubules of dactylopores, are locally very abundant and suggest that these features of the colony may have been very brittle.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 587–594, 9 TEXT-FIGS., MAY 1958

ARIKAREEAN RHINOCEROSES FROM SOUTH DAKOTA

MORTON GREEN
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ABSTRACT—Only one species of rhinoceros, *Diceratherium gregorii*, has been described from Lower Miocene deposits in South Dakota. Additional specimens with unworn dentitions adds to the knowledge of this species. *D. armatum* is added to the fauna and is used as a basis for correlating the deposits of Gering type lithology with the John Day formation in Oregon. The temporal range of *Hyracodon* is extended into the early Miocene.

INTRODUCTION

IN 1920, Peterson described *Diceratherium gregorii* from Lower Miocene deposits (*i.e.*, "Lower Rosebud") in South Dakota. Since that time few contributions have been made relative to that fauna and none on rhinoceroses. Neither have there been any rhinoceros remains described from equivalent deposits (Gering and Monroe Creek formations) in Nebraska. The discovery of some remains from Arikaree deposits in South Dakota, though fragmentary, warrants reporting. These specimens were collected by field parties from the Museum of Geology, South Dakota School of Mines and Technology, during the 1953 and 1954 field seasons by J. R. Macdonald and myself.

ACKNOWLEDGMENTS

A research grant from the South Dakota School of Mines and Technology Endowment Association has helped support this project. The drawings were made by Mildred Ahrlin. Thanks are expressed to H. E. Wood, 2nd for suggesting to me the identity of the specimen referred to *Diceratherium armatum*.

MEASUREMENTS

No standard method for measuring upper rhinoceros teeth has yet been recommended. This has led to a diversity of measurements on the part of different authors for the same specimen. In addition, the curvature of the upper tooth modifies the crown measurements as the tooth is worn thus rendering measurements at the crown useless. This is true of the lower teeth also, but to a lesser degree. On the suggestion of H. E. Wood, 2nd (per. comm.) the measurements of the upper teeth given in this paper are as follows. All are taken at the base of the crown at and including the cingulum; antero-posterior dimension is taken along the approximate midline of the tooth through the postfossette, not the ectoloph; transverse dimension is taken across the tooth from the base of the paracone to the opening of the median valley, or, if the median valley is closed, to the approximate center of the lingual side of the tooth. Lower teeth are similarly measured, at the base of the crown, including the cingulum. Antero-posterior diameter is taken from the antero-labial corner to the postero-lingual corner; transverse width is taken across the metalophid.

SDSM LOCALITIES

V5350. SE¼ SW¼ Sec. 26, T. 38 N., R. 44 W.
V5354. Corner of sec. 13, 14, 23, 24, T. 39 N., R. 43 W.
V5358. SE¼ sec. 31, T. 40 N., R. 43 W. and NE¼ sec. 6, T. 39 N., R. 43 W.
V5360. N½ sec. 17, T. 39 N., R. 43 W.
V542. N½ sec. 30, T. 30 N., R. 43 W.
V543. S½ SW¼ sec. 32, T. 40 N., R. 43 W. and NW¼ sec. 5, T. 39 N., R. 43 W.
V545. Sec. 23, T. 39 N., R. 45 W.
V549. NW¼ sec. 35 and S½ sec. 26, T. 41 N., R. 43 W.

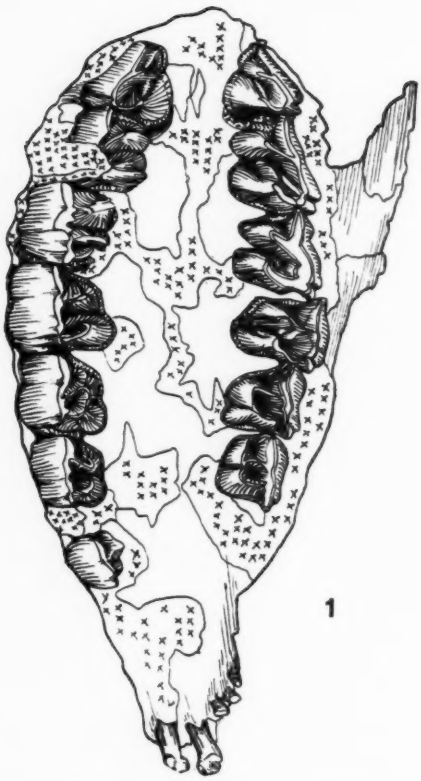
SYSTEMATIC DESCRIPTIONS

Family HYRACODONTIDAE
Subfamily HYRACODONTINAE
HYRACODON APERTUS Sinclair, 1922

Loc. V545. SDSM No. 54141; palate with right I^{1-3}, C, P^2–M^3; partial right mandible with I_{1-3}, P_2–M_3; partial left mandible with P_2–M_3 and two loose incisors.

This specimen was found five feet above the basal ash of the Arikaree deposits and represents an extension of the temporal range of the genus into the early Lower Miocene.

Description.—P^1: protoloph present only as a projecting cusp, the antero-lingual cingulum, not connected to the ectoloph. P^2: similar to the type in that the hypocone



TEXT-FIG. *1*—*Hyracodon apertus* SDSM No. 54141, palate. ×½.

has a posteriorly directed spur. P^3: similar to the type; no posterior spur from the hypocone; small crista on right side, on left side the crista is only a swelling; antecrochet present, crochet absent. P^4: molariform, antecrochet and crista present, median valley open. Molars: with some indication of crista; M^3 unerupted but exposed. The lower dentition is not unusual; M_3 is unerupted. The length of the molar series (M^1–M^3) is 68.8 mm. which is near the upper limit of size range given by Sinclair (1922, p. 74).

TABLE 1—MEASUREMENT IN MILLIMETERS OF *Hyracodon apertus* SDSM No. 54141

	Left	Right
P^1 A–P	11.3	
P^1 Tr	13.4	
P^2 A–P	17.2	17.3
P^2 Tr	18.1	19.7
P^3 A–P	17.7	18.5
P^3 Tr	21.4	21.6
P^4 A–P	19.8	19.5
P^4 Tr	23.3	24.6
M^1 A–P	broken	21.4
M^1 Tr	broken	25.0
M^2 A–P	23.4	24.3
M^2 Tr	broken	25.4
M^3 A–P	22.7	22.5
M^3 Tr	22.3	22.4
M^1–M^3		68.8

Cf. HYRACODON

Loc. V549; No. 54183; partial right mandible with broken P_4–M_3. This specimen is referred here because it is nearer in size to specimens of *Hyracodon* I have seen. The teeth are one-third smaller than those in *Diceratherium gregorii*. If the specimen is correctly referred then the temporal range is extended but slightly as this specimen is from a higher level than the referred *H. apertus*.

Family RHINOCEROTIDAE
Subfamily CAENOPINAE
DICERATHERIUM GREGORII Peterson 1920

Additional diagnostic characters.—Premolars and molars with crista, differing from *D. niobrarense* Peterson. M^{2-3} with well developed crochet.

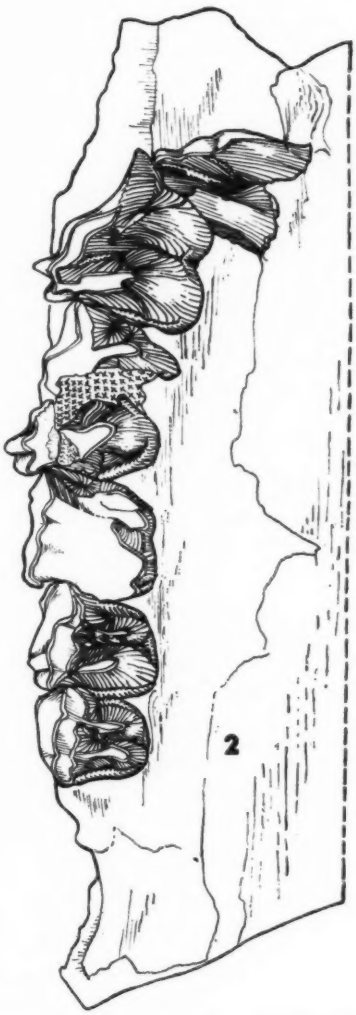
Referred specimens.—Loc. V5354; SDSM No. 54339; right P^{2-4} inner half of M^1. Loc V542; SDSM No. 54165; left M^2. SDSM No. 54198; unerupted M_1. SDSM No. 54188; partial right mandible with roots of P_{2-4}, worn M_{1-2}. Loc. V543; SDSM No. 54144; crushed palate with left roots P^1, P^{2-3}, DP^4 over P^4, M^{1-2}, M^3 unerupted, right P^4–M^2, fragmentary right mandible with roots P_2, P_3–M_2.

All of these specimens are from a nodular zone above the basal ash with the exception of No. 54144 which is from a slightly higher nodular layer.

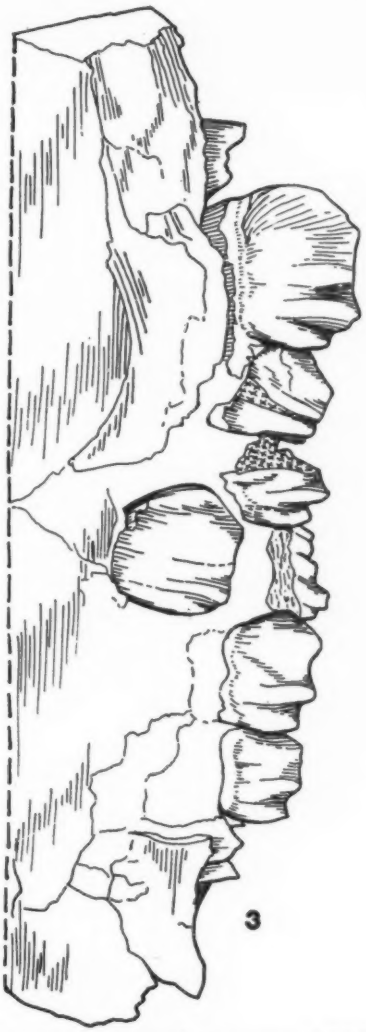
Description of specimens.—No. 54144. P^2 lingual cingulum slightly interrupted by protoloph and metaloph, labial cingulum not strongly developed, weak mure between protoloph and metaloph, crista weakly developed, crochet faintly indicated. P^3: lingual cingulum as in P^2, crista well developed but low in medifossette, crochet strong and double. DP^4; worn and without character. P^4; cingula as in P^3, crista well developed, crochet double, weak mure. M^1:

lingual cingulum poorly developed, strong crochet and crista, median valley opens widely. M^2; as in M^1. M^3; unerupted, with crista and crochet. P_3–M_2; the external wall of the talonid crest is parallel with the long axis of the jaw, the anterior end of the talonid crest does not curve inward in M_{1-2} and only slightly in P_{3-4}.

No. 54339. These teeth are not as heavily worn as those in the type. The labial cingula are more strongly developed than in the teeth of No. 54144 and in this respect bears a greater resemblance to the type specimen.



TEXT-FIG. *2*—*Diceratherium gregorii* SDSM No. 54144, left side of crushed palate. ×½.



TEXT-FIG. *3*—*Diceratherium gregorii* SDSM No. 54144, labial view of left side. ×½.

No. 54165. M^2; The anterior half of the ectoloph is missing. The median valley opens widely.

No. 54198. M_1; same configuration as M_1 in No. 54144.

No. 54188. M_1; much worn and the outer enamel is missing. M_2; also worn and the back end is broken. There is no evidence of M_3 having been present. The bone behind M_2 is pitted but not deeply. Removal of the bone displays no sign of any root. This speci-

TEXT-FIG. 4—*Diceratherium gregorii* SDSM No. 54144, right side of palate. ×½.

men is referred here because of size and because the external portion of the talonid wall is parallel to the long axis of the jaw.

Comments.—The lingual cingula in the type are well developed. My measurements of the type are close to Peterson's (1920, p. 424) except for M^{2-3} where my measurements of transverse width are much narrower.

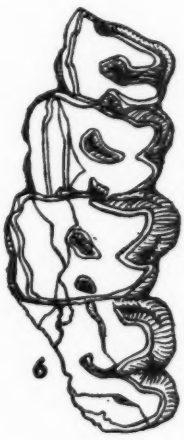
TEXT-FIG. 5—*Diceratherium gregorii* SDSM No. 54144, left lower jaw. ×½.

This species seems valid on the cranial characters given by Peterson (1920, p. 421). No cristae are present in the teeth of *D. niobrarense* Peterson. Crochets in *D. niobrarense* are simple; in *D. gregorii* they are double. *M*³ in *D. niobrarense* possesses a crista but no crochet. M^3 seems to be relatively smaller in *D. gregorii*. The lingual cingulum in both the premolars and molars is strongly developed and continuous around the protoloph and metaloph in *D. niobrarense*. In *D. gregorii* these cingula are not so strongly developed and are interrupted by the lophs. The doubling of the crochet in *D. gregorii* is sometimes seen in *D. cooki* Peterson. The interrupted cingulum is also present in *D. cooki* and *D. annectens* (Marsh). It is continuous in *D. armatum* Marsh in some specimens.

DICERATHERIUM ?GREGORII

Loc. V5360: No. 53419; left DP_{2-3}. DP_2 possesses the extra anterior accessory lophid so often seen in rhinoceros deciduous lower teeth. The outer edge of the talonid wall is nearly parallel with the long axis of the jaw. The bone between the two teeth is missing as is the anterior edge of DP_3. These teeth are much larger than corresponding milk teeth in *D. cooki*. DP_2: A–P 30.5 mm.; Tr 13.7 mm.

Loc. V5358: No. 53418; left P^1, DP^{2-3}. These teeth are the proper size for occlusion with the above mentioned lower milk



TEXT-FIG. 6—*Diceratherium gregorii* SDSM No. 54339, right side, ×½.

TABLE 2—MEASUREMENTS IN MILLIMETERS OF *Diceratherium gregorii* UPPER DENTITIONS

	AMNH* 12933	AMNH† 12933		SDSM‡ 54144		SDSM 54144		SDSM‡ 54339	SDSM 54339	SDSM‡ 54165	SDSM 54165
		L	R	L	R	L	R				
P^2 A–P	26			28.4		23.1		25.1	21.7		
P^2 Tr				27.3		27.3		28.5	29.3		
P^3 A–P	31			29.8		25.6		27.4	24.2		
P^3 Tr	44			32.7		32.7		37.0	37.5		
DP^4 A–P				29.6		28.2					
DP^4 Tr				30.7		30.7					
P^4 A–P	34				33.0		29.0	30.2	26.4		
P^4 Tr	48				36.5		36.4	42.7	37.2		
M^1 A–P	38			41.0	41.4	37.8	34.8			41.8	36.6
M^1 Tr	45			34.4	37.6	32.6	37.1				
M^2 A–P	45		44.5	44.5	43.7	36.2	36.9				
M^2 Tr	47		38.6	39.6	40.7	37.4	38.4				
M^3 A–P	38		38.7	37.6		24.6					
M^3 Tr	44		28.5	27.0		29.7					
P^2–P^4		87.6	86.0	82.8		76.4		78.8	71.5		
M^1–M^3		115.5	112.3	102.0							

* After Peterson 1920.
† These measurements were taken by the author in 1955. A–P is across the ectoloph: Tr is across the widest portion of the tooth. They are included for comparison with Peterson's measurements.
‡ These measurements are taken across the ectoloph and greatest width for comparative purposes. All other columns are measured as stated in the text.

teeth. They are barely worn. P^1; parastyle in direct line with ectoloph, not twisted toward lingual side. DP^2; lingual cingulum raised into sharp cone at median valley, crista not extending across tooth as in deciduous teeth in *D. cooki* but only part of the way as in *D. annectens*. DP^3; lingual cingulum interrupted by lophs, crista as in DP^2, median valley opens widely.

TABLE 3—MEASUREMENTS IN MILLIMETERS OF *Diceratherium gregorii* LOWER DENTITIONS

	SDSM 54144	SDSM 54188	SDSM 54198
P_3 A–P	28.4	22.6*	
P_3 Tr	17.3		
P_4 A–P	33.3	24.5*	
P_4 Tr	19.5*		
M_1 A–P	34.2	29.6	34.9
M_1 Tr	22.0	17.3	20.0
M_2 A–P	23.0	17.8	

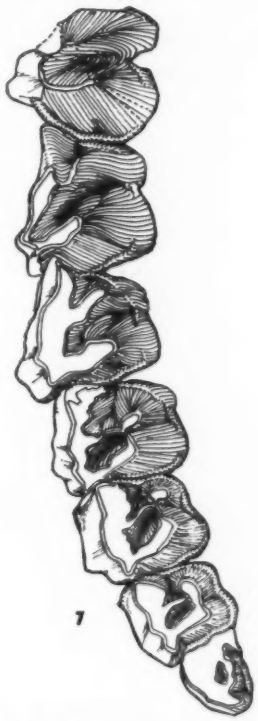
* Approximate measurements.

DICERATHERIUM ARMATUM Marsh 1875
= D. LOBATUM Troxell 1921

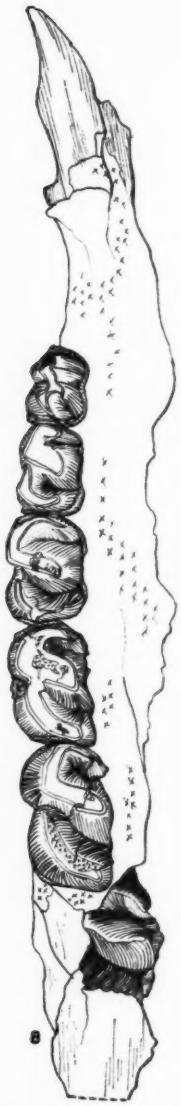
Loc. V5350. SDSM No. 53584. Left P^2–M^3, right I^2, P^2–P^4, left mandible with C, P_3–M_3, portion of right mandible with C, P_2–M_3.

Loc. V543. SDSM No. 54150, left M_2.

Description.—Upper dentition. I^2: slightly crushed; inner moiety about one half diameter of outer. P^1: medifossette barely isolated; cingula well developed. P^2: anterior, lingual, and posterior cingula well developed and continuous; hypocone connected to protocone by narrow bridge (mure); metaloph thin, curving anteriorly, connected to hypo-



TEXT-FIG. 7—*Diceratherium armatum* SDSM No. 53484, left side: P^1 drawn in reverse from right side. ×½.



TEXT-FIG. 8—*Diceratherium armatum* SDSM No. 53484, left lower jaw; P_2 drawn in reverse from right side. ×⅓.

cone near its anterior end; hypocone round. P^3: cingula as in P^2; faintly indicated crista and crochet; metaloph thin, curving anteriorly and connected to protocone; hypocone connected to metaloph by thin bridge; hypocone slightly compressed antero-posteriorly. P^4: similar to P^3 but hypocone more compressed. M^1: lingual cingulum lacking except remnants on protoloph and metaloph at median valley; antecrochet bulbous. M^2: as M^1 except cingular remnant on protoloph only. M^3: an unerupted tooth, typically rhinocerotoid. Lower dentition. C: triangular, robust. The length of the diastema is unknown. In the restored portion of the jaw the diastema was estimated on the basis of dentitional size. Cheek teeth: not peculiar, typically rhinocerotoid. M_3 is unerupted but exposed in the jaw.

Loc. V543. No. 54150, a left M_2 is referred here because of its size. It is from the same level as that of No. 54144, *D. gregorii*.

Discussion.—I have not seen the type of *D. lobatum* or *D. armatum* but judging from the published figures and descriptions the South Dakota specimen is referable to *D. armatum* and *D. lobatum* is synonymous with it. Troxell's (1921) figure of the type of *D. armatum* seems to be a much clearer illustration than that of Peterson (1920). Comparison of measurements among the several specimens shows a degree of size range not incompatible with accepted limits of variation. It is the variation of enamel pattern seen in the few known specimens which is most striking. USNM No. 11682 from Montana has the most worn dentition. Consequently, its enamel pattern is reduced to simplicity and the medifossettes are closed in P^2–M^1 and possibly in M^2. In the type specimen, there is a true mure in P^{2-3} and cristae or at least rudiments of cristae in P^{2-4}. SDSM No. 53484 has true mures in P^{2-4} and cristae in P^3. The type of *D. lobatum* is an exaggerated variation in which the cristae and crochet are more prominent (in P^{3-4}) than is usual. Each of these specimens displays the development of mures and cristae in varying degree. This, along with size proximity is deemed sufficient for placing *D. lobatum* Troxell in the synonymy of *D. armatum* Marsh.

STRATIGRAPHY AND CORRELATION

Current stage of exploration and study of the fauna collected prevents anything more conclusive than to state that the bulk of the SDSM collections come from deposits of Gering type lithology and that these specimens represent a lower Arikareean fauna from a probable Gering equivalent. Whether these deposits are actually an extension of

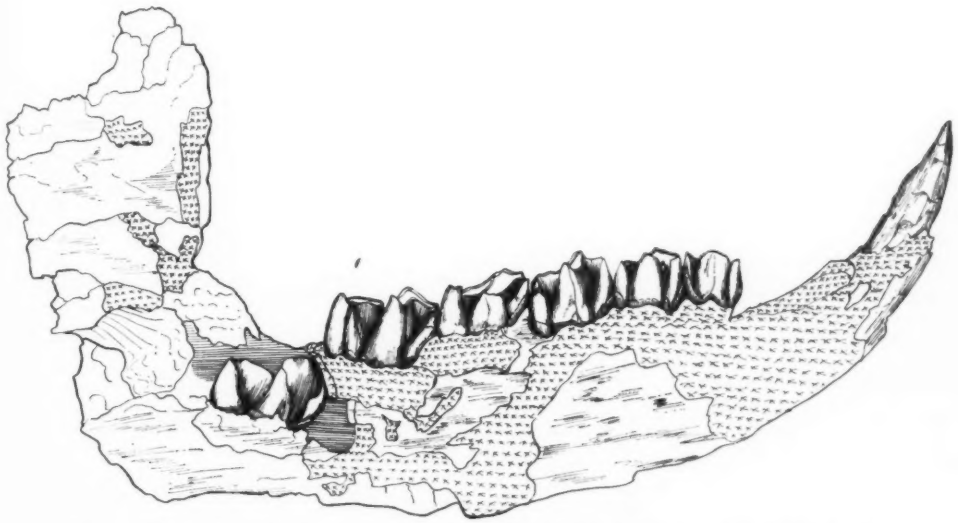
TABLE 4—MEASUREMENTS IN MILLIMETERS OF *Diceratherium armatum* SDSM No. 53584

Upper Dentition			Lower Dentition		
	L	R		L	R
I^2 A–P		14.5	C Tr	27.4	
I^2 Tr		8.6	P_2 A–P		31.7
P^1 A–P		27.5	P_2 Tr		23.4
P^1 Tr		25.5	P_3 A–P	42.5	40.2
P^2 A–P	32.5	31.8	P_3 Tr	25.5	29.3
P^2 Tr	40.2	38.6	P_4 A–P	49.9	46.3
P^3 A–P	34.6	38.6*	P_4 Tr	30.0	31.4
P^3 Tr	49.3	46.1*	P_2–P_4		117.5
P^4 A–P	37.9	49.8*	M_1 A–P	49.3	50.6†
P^4 Tr	53.8	46.5*	M_1 Tr	35.5	31.7†
P^1–P^4	150.0		M_2 A–P	59.0	62.0
P^2–P^4	104.3	116.1*	M_2 Tr	34.8	37.7
M^1 A–P	46.2		M_3 A–P	60.7 (approximate)	
M^1 Tr	54.8		M_3 Tr	32.4	34.4
M^2 A–P	52.6		M_1–M_3	174.5 (approximate)	
M^2 Tr	56.9				
M^3 A–P	55.1				
M^3 Tr	53.5				
M^1–M^3	155.5				

* Crushed.
† Crushed laterally and spread apart antero-posteriorly.

the Gering formation is yet to be determined. These beds are those called, "Rosebud beds," by Gidley (1904). The name, "Wounded Knee fauna," has been proposed by Macdonald (in press) to replace the names, "Lower and Upper Rosebud Faunas" of Matthew (1907). I support this change wholeheartedly.

The presence of *D. armatum* from the middle and upper portion of these Gering-like deposits suggests a correlation with the fossiliferous vertebrate beds of the John Day



TEXT-FIG. 9—*Diceratherium armatum* SDSM No. 53484, left lower jaw, lingual side; P_2 drawn in reverse from right side. ×½.

formation. The type of *D. armatum* is from the John Day. This correlation has been suggested by Green (1954) as opposed to the suggestion of Schultz and Falkenbach (1949) that the John Day is correlative with the Harrison formation basing their conclusion on oreodon phylogeny. Unfortunately, the precise stratigraphic position of John Day specimens, particularly old types, is not known. One reason for the diametrically opposed opinions on correlation of the John Day with Great Plains deposits is that the John Day may encompass a greater time span than has been suspected and Gering through Harrison equivalents may exist within the confines of the John Day formation.

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SOME PROBLEMATICAL CARNIVORES FROM THE FLORIDA MIOCENE

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ABSTRACT—The taxonomic restudy of three carnivores from the Florida Miocene is based on new material which has been discovered subsequent to the original descriptions. The new genus *Absonodaphoenus* is erected to include the species *bathygenus*, formerly placed in the genus *Parictis*. The reported genera of Miocene carnivores *Parictis*, *Daphoenus*, *Mesocyon* and *Aelurocyon* are not represented among the known forms from the Florida Tertiary.

INTRODUCTION

THE carnivores discussed in this contribution have been shifted about through various genera, in regard to their taxonomic assignment, and in most cases without the authors adequately citing the methods and materials used in the comparisons of these forms.

The described material is fragmentary at best and unfortunately, in the case of *Temnocyon*, most of the fragments that are available show characteristics that are common to both genera to which they have been referred, rather than those portions which exhibit characters that are peculiar to *Temnocyon* alone.

New evidence has been compiled, in some cases not available to previous research workers, which now warrants the generic revision of these rarer Miocene forms.

The following abbreviations are used:

A.M.N.H., the American Museum of Natural History
H.C., Collection of Harold Cook, Agate, Nebraska
M.C.Z., Museum of Comparative Zoology
N.S.M., Nebraska State Museum
C.M., Carnegie Museum
C.N.H.M., Chicago Natural History Museum
S.D.S.M., South Dakota School of Mines

ACKNOWLEDGMENTS

Thanks are due to the following people who aided me by supplying actual material or casts of specimens from collections in their respective institutions: Prof. Bryan Patterson of the Museum of Comparative Zoology; Dr. G. G. Simpson and Mrs. Rachael Nichols of the American Museum of Natural History. I am indebted to Dr. Herman Gunter for permission to use the material in the collections of the Florida Geological Suvey and to Dr. H. Cook for the loan of specimens in his collection.

The illustrations were drawn by Miss Patricia Washer of the Museum of Comparative Zoology and Mr. Andrew Janson of the Florida Geological Survey.

Family CANIDAE Gray, 1821
Subfamily SIMOCYONINAE Zittle, 1893
Genus TEMNOCYON Cope, 1878

TEMNOCYON sp.

Text-figs. 1,2

Mesocyon iamonensis Simpson, 1928, p. 252–255; 1930, p. 159–161, fig. 5.
?Temnocyon sp. Simpson, 1932, p. 14.
Temnocyon? Pirkle, 1956, p. 226.

Hypodigm.—Talonid of left M_1, F.G.S. V-500; trigonid of right M_1, F.G.S. V-3494; trigonid of left M_1, F.G.S. V-3494A; right M_1, F.G.S. V-1213, in jaw fragment, F.G.S. V-1214.

Horizon and locality.—Lower Miocene; all material from Pit No. 2, Franklin Phosphate Company, Newberry, Alachua County, Florida, with the exception of F.G.S. V-1213 and F.G.S. V-1214 which are from the Griscom Plantation (=Luna Plantation), Leon County, Florida.

Material used for comparison.—The following specimens were used for comparison with the Florida material: *Temnocyon altigenis* type A.M.N.H. 6855; *T. altigenis* A.M.N.H. 6856; *T. venator* type H.C. 223; *T. percussor* type H. C. 116; *T. ferox* A.M.N.H. 6857; *Mesocyon coryphaeus* A.M.N.H. 6860; *M. coryphaeus* A.M.N.H. 6866; *M. hortulirosae* type M.C.Z. 2102; *M. hortulirosae* M.C.Z. 2883; *M. geringensis*

type N.S.M. 1092; *M.* sp. A.M.N.H. 27753 and 6863.

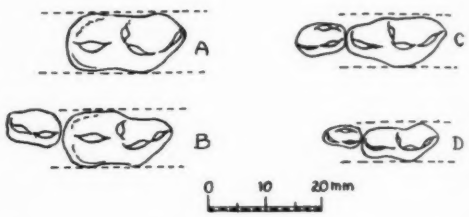
Discussion.—The close resemblance of the lower dentition of *Mesocyon* to that of *Temnocyon* has been the cause of much confusion in assigning the correct generic name to these animals. This is evidenced in *Mesocyon coryphaeus*, which was classified originally as *Temnocyon coryphaeus*. Scott (1890) made this species the generic type for *Mesocyon*, although Loomis (1936, p. 49) incorrectly lists *Temnocyon josephi* as being the generic type for *Mesocyon*. Dr. G. G. Simpson (1928) referred the material from Newberry, Florida, to *Mesocyon iamonensis* but later tentatively referred this same material to the genus *?Temnocyon*. That these specimens are the same in both cases was verified by the vertebrate catalog of the Florida Geological Survey. The error in assigning these fragments to *Mesocyon iamonensis* was carried over from an identification in an unpublished manuscript of Dr. W. D. Matthew (Simpson, 1928, p. 255). This error probably would not have been made had the diagnostic M_2 of *Temnocyon* been preserved. This molar has its two centrally located cusps in tandem rather than being located on the lingual and labial edges of the anterior end of this key tooth as is evident in *Mesocyon*. Since this second lower molar is not represented in the Florida material, another means was sought to distinguish and separate these two morphologically similar canids.

Close comparison of the first lower molar of *Temnocyon* with that of *Mesocyon* established the following differences between the carnassials of the two genera.

In *Temnocyon*, the talonid is much wider proportionally than the trigonid, having a trenchant heel (as does *Mesocyon*) with the hypoconid being more centrally located than that of *Mesocyon* (text-fig. 1). The lower dentition of *Temnocyon* and M_1 in particular is proportionally more massive and comparatively larger, in relation to the lower jaw, than these same teeth in *Mesocyon*.

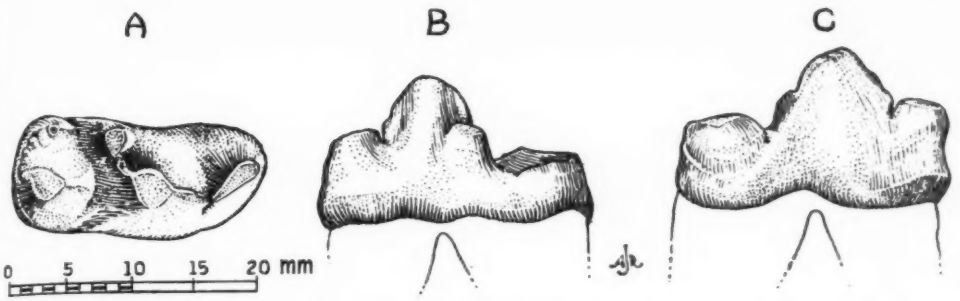
The Florida form more nearly approaches *T. percussor* of the known forms although the latter is somewhat larger than those fragments from Newberry and the Griscom Plantation. This size difference is well within the variation range of species of the same genus of carnivores of which sufficient material is known to evaluate this variation by biometric analysis.

The Florida specimens conform very well to the known species of *Temnocyon* and there can therefore be little doubt that they must be referred to the genus *Temnocyon* (text-fig. 2). The writer hesitates to go beyond a generic assignment when such assignment is based on the material that is now available and will designate these specimens as *Temnocyon* sp. until additional evidence is compiled to warrant a more specific classification.



TEXT-FIG. *1*—Comparative proportions of trigonid & talonid and cusp arrangement of lower molars of *Temnocyon* and *Mesocyon*. A, *Temnocyon* sp., F.G.S. No. V-1213, occlusal outline of right M_1. B, *Temnocyon altigenis*, A.M.N.H. 6856, occlusal outline of right M_1 and M_2. C, *Mesocyon geringensis*, N.S.M. 1092, occlusal outline of right M_1 and M_2. D, *Mesocyon coryphaeus*, A.M.N.H. 6863, occlusal outline of right M_1 and M_2.

In checking the literature pertaining to the genus *Temnocyon*, it was noted that Dr. F. B. Loomis (1936, p. 49) stated that "Cook's *T. venator* is surely an *Enhydrocyon*." This statement by Loomis in regard to Cook's species belonging in the genus *Enhydrocyon* is particularly confusing, inasmuch as Loomis figured the lower M_1 of both genera correctly and the type of Cook's species (H.C. 223) has a strong metaconid present on M_1 which is absent (as it should be) in Loomis' figure of a typical *Enhydrocyon* (1936, fig. 5). Since *Temnocyon venator* has a definite metaconid on M_1 and the lack of this cusp is an identifying feature of *Enhydrocyon*, this suggested change of classification is not feasible and Cook's identification must remain as valid.



TEXT-FIG. 2—*Temnocyon* sp., right M_1, F.G.S. V-1213. A, occlusal view. B, lingual view. C, labial view.

Genus ENHYDROCYON Cope, 1879
ENHYDROCYON SPISSIDENS (White)
Text-fig. 3

Aelurocyon spissidens White, 1947, p. 497,498, fig. 1A,B; Romer, 1948, p. 1–11; Olsen, 1956, p. 1–5.

Hypodigm.—Partial left mandible with P_4 and M_1 and alveoli for P_2, P_3 and M_2, M.C.Z. 4246 (type of *Aelurocyon spissidens*); partial left mandible with P_4–M_2 and alveolus for M_3, M.C.Z. 7310.

Horizon and locality.—Lower Miocene, Thomas Farm, Gilchrist County, Florida.

Material used for comparison.—Casts of the following specimens were used for comparison: *Aelurocyon brevifacies*, type C.M. 1590; *Enhydrocyon crassidens*, type A.M.N.H. 12886; and *Euoplocyon praedator*, M.C.Z. 17301.

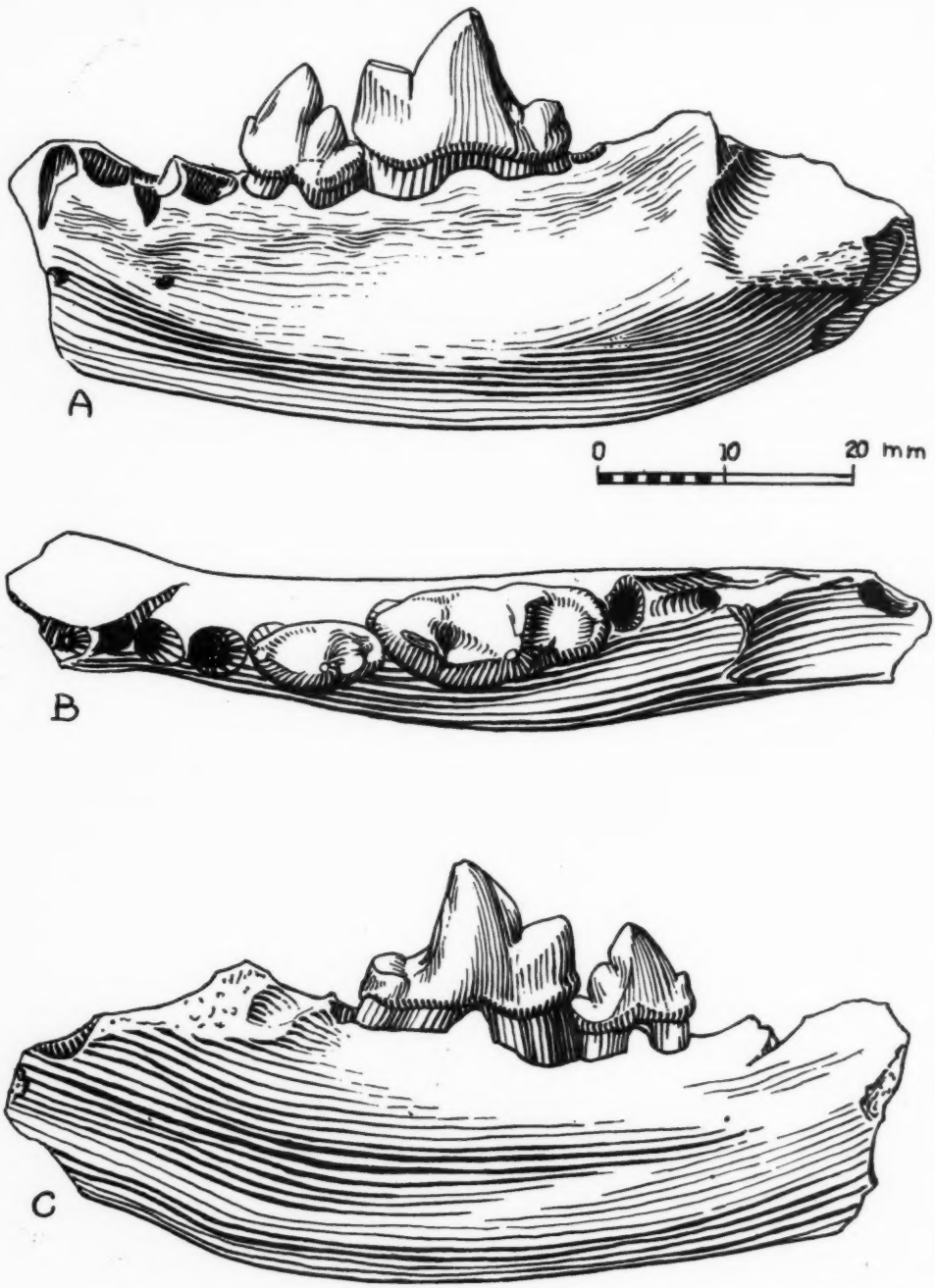
Discussion.—The catalog of fossil mammals, which is contained in the Museum of Comparative Zoology at Harvard University, has an entry in Dr. T. E. White's handwriting as follows, "4246. *Enhydrocyon spissidens* n. sp." This same specimen became the type for *Aelurocyon spissidens* which White (1947) described a decade ago but no mention is made of this earlier (and correct) identification by him.

An additional specimen of this carnivore, consisting of a fragmental left mandible bearing P_4, M_1, and M_2 (M.C.Z. 7310), has been recently recovered from the Thomas Farm quarry.

On comparing these only known remains of White's *Aelurocyon spissidens* with specimens of *Enhydrocyon crassidens* and *Aelurocyon brevifacies*, the following observations were made: the lower premolars in general, and P_4 in particular, of *Aelurocyon* are heavier and more nearly approach the size of the carnassial, being crowded together in the tooth row with little or no diastema. These same teeth in *Enhydrocyon* and the Thomas Farm form are small and lighter in build when compared with the lower carnassial and have a small but positive diastema present between the premolars. The first lower molar of *Aelurocyon* has a definite lingual constriction in the region of the valley which separates the paraconid from the protoconid, a condition not present in the Florida species or in the specimen of *Enhydrocyon* that was examined. Both of the above genera lack a metaconid on M_1, having instead a ridge running from the peak of the protoconid to the base of the entoconid on the posterolingual face of the protoconid. This ridge is referred to by White (1947, p. 498) as "a vestige of the metaconid represented by a minute tubercle." *Euoplocyon* has this same ridge in place of the metaconid but otherwise in no way closely resembles the Thomas Farm canid.

The presence of a third lower molar is established (at least in one specimen, M.C.Z. 7310) by the alveolus which has been partly preserved. In Cope's (1879, p. 935) description of the genus, he indicates M_2 and M_3 as being questionable. This was due to incomplete material as far as this region is concerned. White's type was broken in such a way that this same area was missing from the specimen, although a nutrient foramen is present in the type, indicating a possible M_3.

M_2 in *Aelurocyon* is nearly circular in shape as compared with the oval outline of this same tooth in *Enhydrocyon*. The two



TEXT-FIG. 3—*Enhydrocyon spissidens*, partial left mandible with P_4 and M_1 (type) M.C.Z. 4246. A, labial view. B, occlusal view. C, lingual view.

principal cusps of *E. spissidens* are located on the lingual and labial edges of the anterior end of this second lower molar with the protoconid being somewhat the larger of the two cusps.

My observations, based on the above comparisons, bear out White's original notation that the species *spissidens* belongs in the genus *Enhydrocyon*.

Subfamily AMPHICYNODONTINAE Simpson, 1945

Genus ABSONODAPHOENUS, n. gen.

ABSONODAPHOENUS BATHYGENUS (White)

Text-figs. 4,5

Daphaenus[1] *caroniavorus* White, 1942, p. 5, pl. 1, fig. 1.

Parictis bathygenus White, 1947, p. 500, figs. 2A,B,C (in part, including type).

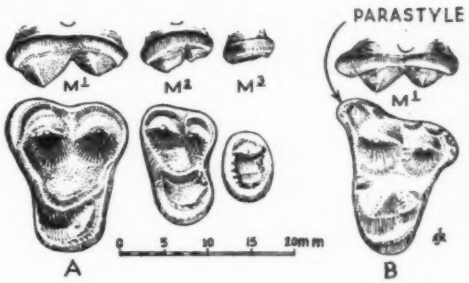
Hypodigm.—Left M^1 and M^3 M.C.Z. 3727 (type of *Daphaenus caroniavorus*); partial left mandible with P_4 and M_2, genotype of *Absonodaphoenus bathygenus* (type of *Parictis bathygenus*) M.C.Z. 3931; left mandible with P_2 and M_2 and alveoli for P_1 and M_3, M.C.Z. 7017; right mandible with P_2 and M_2 and alveoli for canine and P_1 and M_3, F.G.S. V-5693; right M^2, M.C.Z. 7295; left P_3, F G.S. V-5761, and P_4, F.G.S V-5762.

Horizon and locality.—Lower Miocene, Thomas Farm, Gilchrist County, Florida.

Generic characters.—Dental formula: $I_?^?$; C_1^1; P_4^4; M_3^3. Upper M^1 with protocone and metaconule completely subordinated in low, sharply defined roughly U-shaped crest, continuous with external cingulum on M^{1-2}. The external crest and external cingulum join at the anterolingual base of the paracone and the posterolingual base of the metacone forming a crescent shaped shelf on M^{1-2}. This same internal crest is present on M^3 but having a flat shelf in place of the raised cingulum as found on the first two molars. The paracone is higher than the metacone on M^{1-2}, but these cusps are completely subordinated in a low, anteroposterior ridge on M^3. Central valley shallow on M^1, becoming shallower and flatter on M^{2-3}. No definite parastyle present.

Lower premolars are well spaced with separating diastema between each tooth.

[1] The original spelling of this generic name is *Daphoenus* (Leidy, 1853).

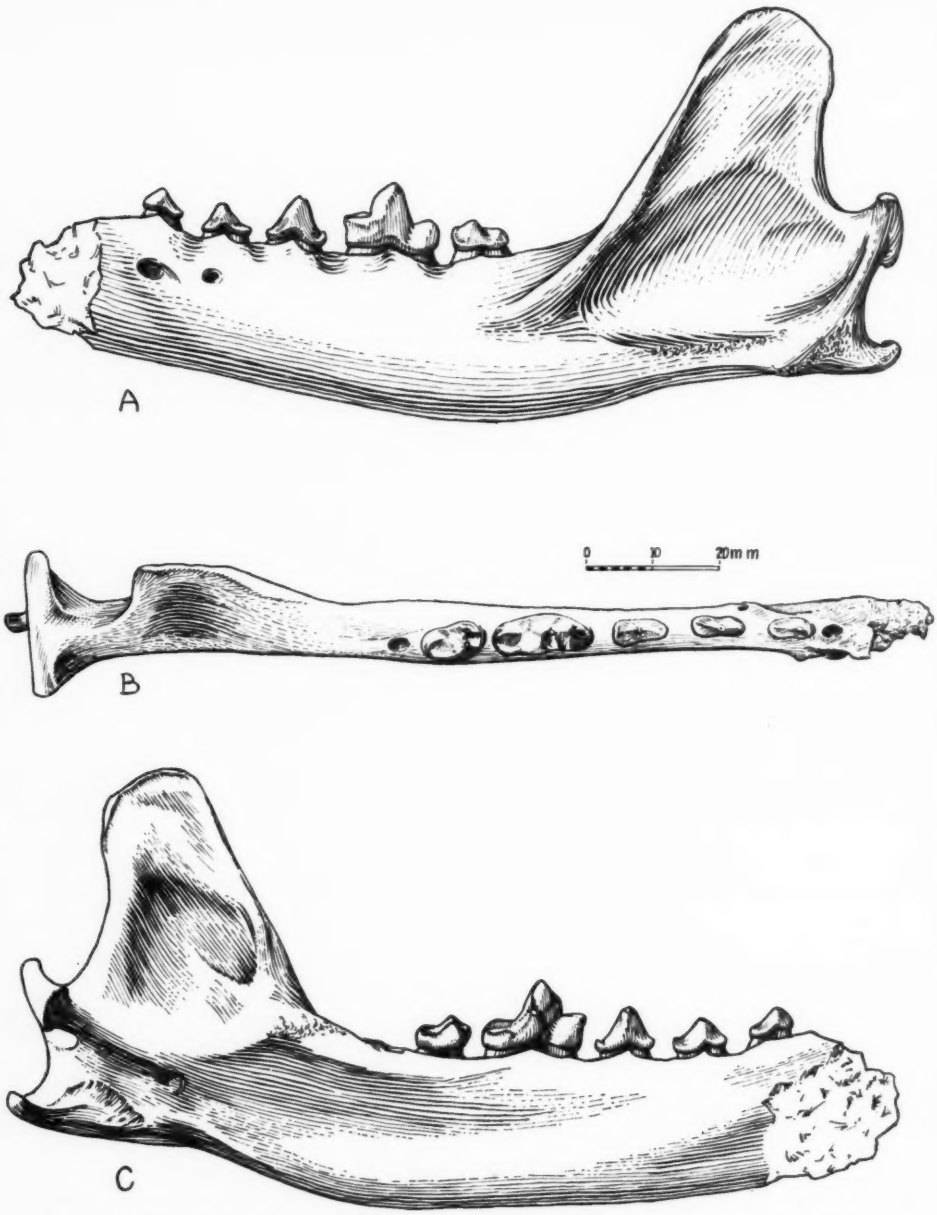


TEXT-FIG. 4—Morphologic differences in the upper molars of *Absonodaphoenus* and *Daphoenus*. A, *Absonodaphoenus bathygenus*, M.C.Z. 3727, occlusal and labial view of left M^1, M^2, and M^3. B, *Daphoenus vetus*, F.G.S. V-5763, occusal and labial view of left M^1.

Premolars are low in relation to the carnassial. P_4 without or with slight posterior accessory cusp. M_1, with trigonid narrow relative to width of talonid. The metaconid on M_1 is internal rather than posterinternal to the protoconid. M_2 is short and wide with low cusps having the metaconid and protoconid equal distance from the anterior edge of the tooth and placed on the lingual and labial margins of the molar. Cusps are blunt with shallow valleys.

Materials used for comparison.—Specimens of *Amphicyon ambiguus*, M.C.Z. 8918 and M.C.Z. 8919; *Amphicyon eseri*, M.C.Z. 9201, *Daphoenus vetus*, F.G.S. V-5761, and the following casts were used for comparison: *Parictis dakotensis* type, S.D.S.M. 2476; *Parictis* sp., C.N.H.M. P.27157; *Cephalogale filholi*, M.C.Z. 8929; *Plesictis palustris*, M.C.Z. 8915; *Plesictis stenogalensis*, M.C.Z. 8916; *Amphicynodon rossignoli*, M.C.Z. 8921; *Daphoenus vetus*, M.C.Z. 4068; *Daphoenus inflatus*, M.C.Z. 4067; *Daphoenus hartshornianus*, A.M.N.H. 12450, A.M.N.H. 9757; *Daphoenus nebrascensis* type C.M. 491. Published descriptions and figured specimens that were used when actual material was not available are referred to in the text of the discussion.

Discussion.—In White's (1942, p. 5) original description of *Daphaenus caroniavorus*, he noted that, "The teeth appear to be somewhat degenerate, and when it becomes better known it may be necessary to erect a new genus for it." In his (White, 1947, p. 502) discussion of *Parictis bathygenus*, he



TEXT-FIG. 5—*Absonodaphoenous bathygenus*, left mandible, M.C.Z. 7017. A, labial view. B, occlusal view. C, lingual view.

hesitated to erect a new genus for this form, based on the material then available, and referred his new species to a known genus. However, he later recognized that this species was not of the genus *Parictis*, but represented a new and as yet undescribed genus (personal communication, May 1956).

The upper dentition assigned by White

to *Paractis bathygenus* has already been discussed and referred to *Cynodesmus iamonensis* by the writer (1956, p. 10) in a previous contribution.

Since no adequate generic category is available for this comparatively rare carnivore, the new genus *Absonodaphoenus* is here proposed for the Thomas Farm species *bathygenus*.

The upper and lower dentitions of this rare carnivore are markedly different from any of the other carnivores of comparable size that occur at the Thomas Farm or that are known from other deposits of similar age. The upper molars occlude with the lower molars to the same degree as different individuals of the same species of a living canid and can be assigned to *Absonodaphoenus* with some degree of certainty.

Although White (1942) described the upper molars of *Absonodaphoenus* as representing a new species of *Daphoenus*, these teeth do not bear out his diagnosis. In all of the species of *Daphoenus* that were examined, a definite parastyle was present on M^1 (text-fig. 4B). This parastyle is absent on the known specimen of *Absonodaphoenus*. The height of the paracone and metacone on M^1 are nearer the same height in *Daphoenus* as opposed to a larger paracone in the species *A. bathygenus* (text-fig. 4).

When the Florida form is compared with the known species of *Paractis* the differences between the two genera are quite apparent. There is no shelf between the external cingulum and the protocone in the upper molars of *Paractis* and the protocone is a high definite cusp as compared with the protocone that is subordinated in the internal crest as is found in *Absonodaphoenus*.

This latter genus also has a lingual constriction of the heel of M^1 and M^2, not found in *Paractis*.

The lower premolars of *Paractis* are larger when compared with the carnassial, having no diastema between them, being instead crowded to such a degree as to place them diagonally in the tooth row. The known specimens of *Absonodaphoenus* have well spaced premolars with no accessory cusps except for a vestigate of one on P_4 of M.C.Z. 3931. The entoconid and hypoconid form a basined heel to M_1 in *Paractis* but the hypoconid is much the higher of the two cusps in *Absonodaphoenus*, forming a nearly trenchant heel to this tooth.

Of all the examined specimens of lower dentition, *A. bathygenus* most nearly approaches the European species *Cephalogale filholi* in general form and proportions, except for having slightly smaller premolars when compared to the molars. The upper molars of *A. bathygenus* compare well with the general form and structure of those found in *Amphicyon eseri* from the Miocene of Europe but are not closely allied to any known genera from North America.

Although Loomis (1932) described and figured a new species of *Pachycynodon* from South Dakota which has many of the features of the Thomas Farm genus, the heel of M_1 is basined and the upper dentition does not exhibit the third molar.

Collectors visiting the Gilchrist County, Florida, quarry have in the past two years enjoyed finding complete skulls of species heretofore known only from isolated teeth. It is hoped that investigations in the near future will meet with the same success in the case of *Absonodaphoenus*.

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NEW PLEISTOCENE *ASINUS* FROM SOUTHWESTERN ARIZONA

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ABSTRACT—A new species of *Asinus* is described and related to *A. mexicanus* (Lance) from Hemphilian, middle Pliocene deposits of Yepomera, Mexico. The new species, *A. pons*, is from beds of probable Blancan, lower Pleistocene, age of Santa Cruz County, Arizona.

Cheek teeth of the new *Asinus* are about 10 mm. more hypsodont than those of *A. mexicanus*, and indicate a time lapse of as much as one third of Pliocene time between the Hemphillian and Blancan.

INTRODUCTION

THE phylogenetic history of the horse has received considerable attention from paleontologists over the last hundred years. A large number of Pliocene and Pleistocene species have been recognized and studied. It seems surprising that, of all these, not a single Pliocene species has been shown to be directly ancestral to a Pleistocene species. It is especially interesting, therefore, that remains of an *Asinus* from beds that appear to be of Blancan (early Pleistocene) age, located in Santa Cruz County, Arizona, belong to a new species almost surely a direct descendant of *Asinus mexicanus* (Lance) from Yepomera, Mexico, of Hemphillian (middle Pliocene) age.

Dr. John F. Lance of the Geology Department of the University of Arizona has kindly permitted the author to describe the new *Asinus* from Arizona and has furnished the following information with regard to the fossil material (personal letter; November 12, 1957).

"The Comosi local fauna is from a small pocket in a hard, red silty sandstone with calcareous cement, exposed in Comosi wash, a small tributary of the Santa Cruz River in the San Rafael valley southeast of Patagonia, Arizona. The locality is in the SW ¼ sec. 30, T23S, R18E (projected), Salt River Base Line and Meridian.

"Only three or four feet of the sandstone is exposed in Comosi and adjacent washes. Overlying the fossiliferous beds is a sequence of red, poorly sorted and poorly consolidated gravel. This gravel, about thirty feet thick at the fossil locality, is interpreted as former flood plain deposits of the Santa Cruz River. The fossiliferous sandstone is structureless, and the attitude has not been determined. The lithology is generally similar to that of beds of Blancan or slightly younger age in other valleys in southeastern Arizona.

"The fauna includes, besides the horse remains, teeth and limb bones of *Tanupolama* cf. *T. blancoensis*, the jaws of a large marmot identified by C. A. Repenning as *Paenemarmota* sp., a partial skull of a large vulture being studied by Hildegarde Howard, fragmentary metapodials of a cervid or antilocaprid, and parts of the carapace of a large turtle. The equid remains represent by far the largest part of the material collected. The age of the fauna is not certain, but I tentatively consider it to be Blancan."

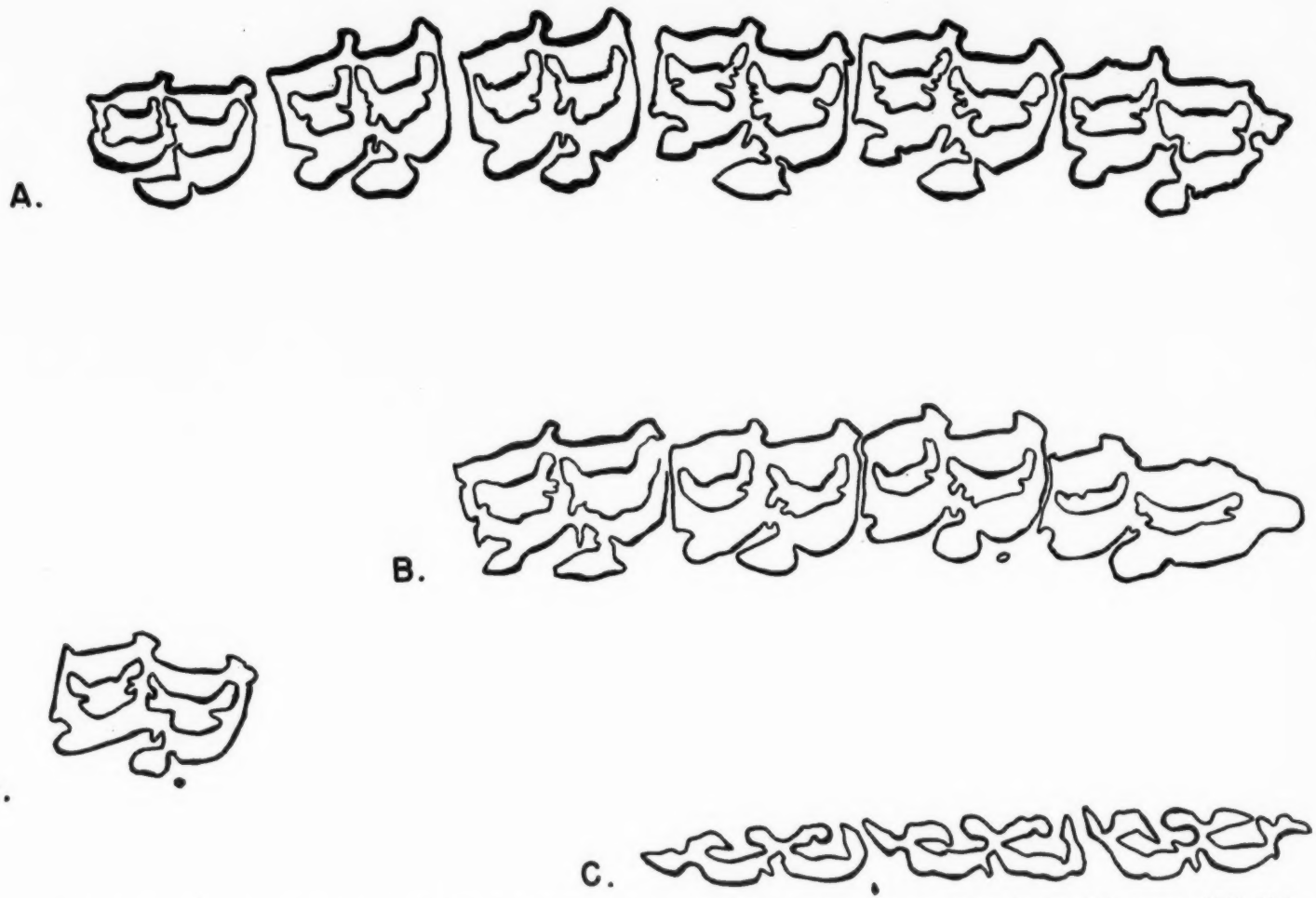
The illustrations were made by F. Wimsatt, University of Arizona. They were drawn in projection by the artist. The section (text-fig. 1A) is a nearly plane surface so that there is little or no distortion in the drawing. Text-fig. 1B, however, was turned at a slightly oblique angle and the teeth, consequently, appear narrower in the drawing than is indicated by their measurements.

Abbreviations and measurements are as follows:

The measurements, which are in millimeters, are presented in tabular form; they do not include the cementum. The symbols used in the tables and the loci of the measurements are as follows:

AP Antero-posterior diameter measured on the ectotoph of the upper teeth and on the inner border of the lower teeth from the anterior edge of the paralophid to the posterior edge of the hypoconulid.

Tr Transverse diameter measured from the mesostyle to the inner border of the protocone on the upper teeth and across



TEXT-FIG. *1*—A–C—*Asinus pons* Quinn, n. sp., U.A. no. 9. A, right upper cheek dentition, sectioned 29 mm. below the top of the crown of M^1, U.A. no. 9-1. B, right upper deciduous dentition and M^1 of U.A. no. 9-1. C, left lower deciduous dentition, U.A. no. 9-2 reversed in the drawing. D, *Asinus mexicanus* (Lance) from Yepomera, Mexico; deciduous third upper premolar with small accessory style similar to that of the deciduous dentition of *A. pons*. (All figs. natural size.)

the greatest transverse diameter of the lower teeth.

CL Crown length measured on the mesostyle to the base of the enamel on the upper teeth and on the metaconid-metastylid to the base of the enamel on the lower teeth.

PL Protocone length measured on the greatest anteroposterior length of the protocone.

PW Protocone width measured on the greatest transverse diameter of the protocone.

MM Metaconid-metastylid measured on the greatest anteroposterior length of the metaconid-metastylid.

SYSTEMATIC DESCRIPTION

Order PERISSODACTYLA
Family EQUIDAE
Tribe EQUINI
Genus ASINUS Frisch
ASINUS PONS* Quinn, n. sp.

Type.—Right maxillary, U.A. no. 9, deciduous series, M^1 in wear, M^2 erupted but unworn, premolars in place and exposed by section; from Pleistocene deposits, 12 miles southeast of Patagonia, Santa Cruz County, Arizona.

Range.—Probably Blancan, lower Pleistocene.

Distribution.—Southwestern Arizona.

Referred material.—Lower jaw with deciduous dentition, metacarpal and metatarsal, U.A. no. 9 (text-figs. 1C; 2, A-B) from same locality as type.

Diagnosis.—Teeth slightly larger than in *Asinus somaliensis* Noak, protocones shorter with pronounced spur on anterior border as in *A. mexicanus* (Lance), more hypsodont than in *A. mexicanus;* metarsal equal in length to that of *A. somaliensis*, larger and stouter than in *A. mexicanus;* metacarpal longer than in *A. somaliensis.*

Description.—The upper cheek teeth, U.A. no. 9 (text-fig. 1A) are unerupted, except for the first and second molars, and were exposed by sectioning the maxillary 29 mm. below the top of the crown of the first molar. The anterior projection of the parastyle on p^2 is shorter than on most specimens of *A. mexicanus* figured by Lance (1950), agreeing more closely with those of *A. somaliensis* (Stehlin & Graziosi, 1935, p. 6, fig. 2A). The mesostyle is high, narrow and slightly bifurcated as in the type of *A. mexicanus.* The posterior valley of the ectoloph has a prominent rib. The prefossette is simple and large. There is a small pli protoloph and pli protoconule. The postfossette is smaller, and has a pli postfossette and pli hypoloph. The protocone is small, rounded and isolated by a deep, narnow preprotoconal groove and a similar postprotoconal groove. The pli caballin is faintly developed. The hypocone is short and rounded. The hypoconal groove remains open as far as the crown of the tooth is developed.

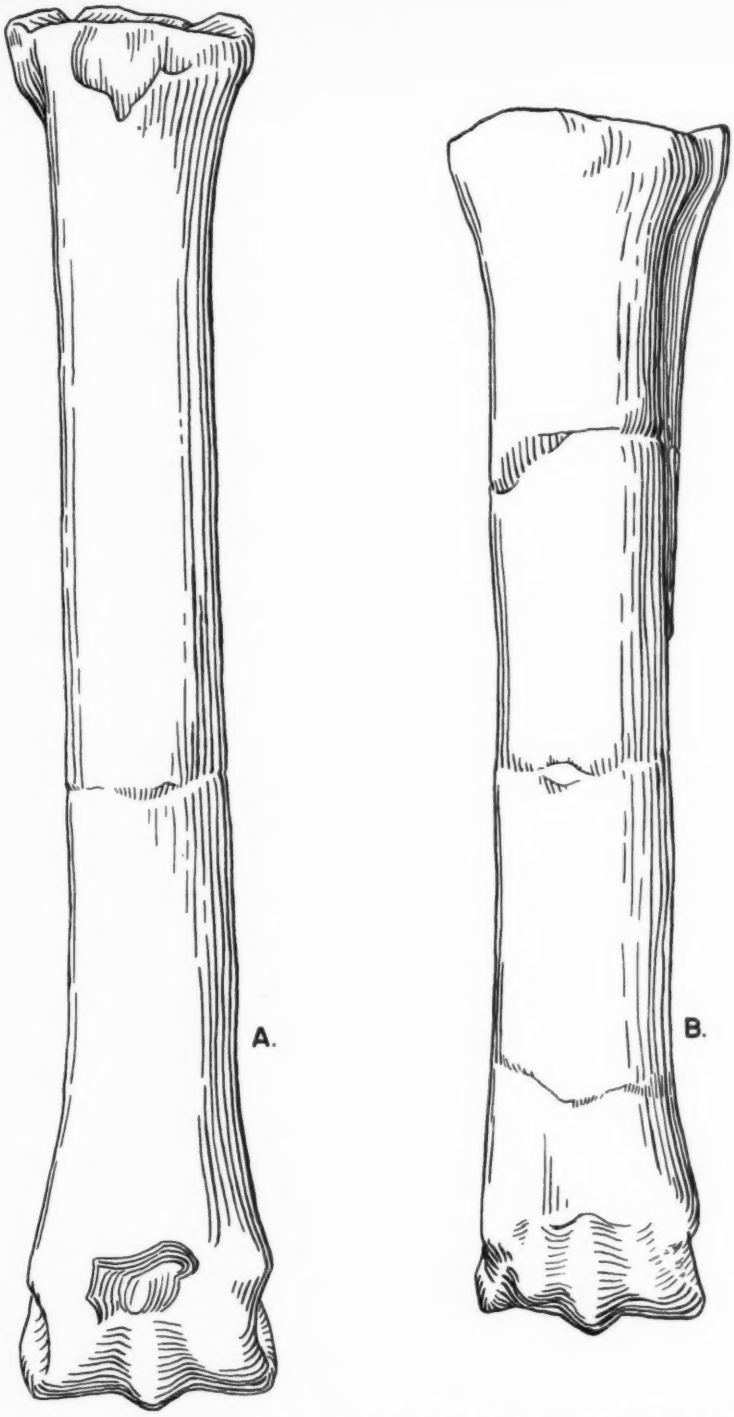
The third premolar has angular styles and broad, shallow valleys on the ectoloph, as in *A. somaliensis.* The prefossette is large, compared to living species, and more rectangular in outline as in *A. mexicanus.* The pli protoloph is prominent. The pli protoconule is small and narrow. Above it there is a double pli prefossette. The postfossette has a long, attenuated cornua anteriorly, similar to that in living species and *A. mexicanus.* The pli postfossette is deep and narrow; the pli hypoloph is small. The protocone has a sharp spur anteriorly, is rounded internally with a very slight indentation, pointed posteriorly and has a strongly concave outer border. The protocone closely resembles that of *A. mexicanus,* especially in possession of the anterior spur. In the living species the anterior and posterior borders of the protocones are more rounded, the protocones are longer and there is a greater tendency to development of the internal groove. The pli caballin is prominent and long. The hypocone is small and pointed posteriorly as in the living species. The hypoconal groove is broad and there is a small hypostylid.

The fourth premolar is closely similar to the third but is sectioned somewhat higher on the crown, probably accounting for a slightly more complex pattern and a longer spur on the protocone.

The first molar is slightly worn (text-fig. 1B), and resembles the premolars except for having narrower, smaller styles on the ectoloph. In the section, the anteroposterior dimension of the first molar is 5/6 that of the occlusal surface. The transverse dimension on the section is slightly greater than

* Pons, L. bridge, thus a bridge between two species, widely separated in time.

TEXT-FIG. 1—A–C—*Asinus pons* Quinn, n. sp., U.A. no. 9. A, right upper cheek dentition, sectioned 29 mm. below the top of the crown of M^1. U.A. no. 9-1. B, right upper deciduous dentition and M^1 of U.A. no. 9-1. C, left lower deciduous dentition, U.A. no. 9-2 reversed in the drawing. *D, Asinus mexicanus* (Lance) from Yepomera, Mexico; deciduous third upper premolar with small accessory style similar to that of the deciduous



TEXT-FIG. 2—*Asinus pons* Quinn, n. sp., U.A. no. 9. A, right metatarsal U.A. no. 9-4, ×¾. B, right metacarpal U.A. no. 9-3, ×¾.

that of the occlusal surface. The protocone is shorter and more rounded. The pli caballin is present but much reduced in size. In the retention of the pli caballin of the molars *A. pons* resembles *A. mexicanus*, and *A. somaliensis* where it is retained. In *A. africanus* Fitzinger, the pli caballin seems to be absent.

The second molar resembles the first.

The third molar lacks the hypocone and is relatively small. There is no trace of a pli caballin.

Deciduous upper dentition.—The deciduous upper teeth of the type, U.A. no. 9, are about half worn away. The first premolar is very small and peg-like. Presumably it is the deciduous one of the series. However, there is no indication of a successor in the bone below.

The second deciduous premolar is long and transversely narrow compared with its successor. The fossettes are narrow and their plications nearly obliterated by wear. The protocone is large and rounded. There is a small pli caballinid.

The third deciduous premolar is less worn. The styles are large and the valleys shallow and flat. The prefossette has the same plications as the permanent P^3. The postfossette which is smaller has only the pli postfossette. Anterior to the protocone there is a small style which is present also on the same tooth and in the same position (text-fig. 1D), as a number of specimens of *A. mexicanus*. Six maxillaries of young animals recovered with the type lack the style. The protocone is large and almost perfectly round. There is a narrow postprotoconal valley and a small pli caballin. The hypocone is short and rounded.

The fourth deciduous premolar is similar to the third, except that the styles are appreciably narrower and the protocone is triangular in shape and pointed posteriorly.

In the little worn dentitions the protocones of the deciduous premolars are smaller and those of the third and fourth deciduous premolars have anterior heels, pointed toes and a concave outer border similar to those of the permanent teeth.

Deciduous lower dentition.—One pair of lower jaws was found with the upper dentitions. These belonged to a young animal and bear the deciduous dentition with the first molar unerupted (text-fig. 1C).

The second deciduous premolar has a backwardly directed spur on the paralophid which reaches the elongated metaconid as in a specimen of *A. mexicanus* (Lance, 1950, p. 46, fig. 5C). The metastylid is restricted at the base and is elongated. There is a small pli hypoconid. The entoflexid is elongated. The entoconid is large and has a long spur directed a little behind the pli hypoconid. There is a definite parastylid. The protoconid is broadly rounded. There is a shallow median valley and a relatively prominent pli caballinid. The hypoconid is slightly indented externally. There is no hypostylid.

The third deciduous premolar has a long, thick, posteriorly directed paralophid. The metaflexid is long and bent inward. The metaconid is deflected inward, attenuated and terminates in a rounded, slightly restricted end. The metastylid is about equally deflected but is shorter and nearly oval. The intermediate valley is deep and broadly V shaped. The entoconid is crescent shaped. There is a large triangular hypoconulid. Externally the tooth has a prominent parastylid which does not reach the summit of the crown. Both the protoconid and hypoconid are broadly rounded, and are separated by a shallow median valley with a prominent pli caballinid.

The fourth deciduous premolar differs from the third in having the paralophid more curved, and in having a deeper, and wider median valley. It has been pointed out (Quinn, 1955, p. 38) that the fourth deciduous premolar presents characters of the permanent molars rather than the premolars. The depth of the median valley of the fourth deciduous premolar, therefore, indicates a more primitive stage of the permanent molars of *A. pons* than is found in *A. somaliensis*.

None of the materials recovered belong to the permanent lower dentition. The lower jaw is essentially complete but since it belongs to a very young animal (less than ten months old) a detailed description would be of little value.

Metacarpal III.—Several metacarpals were recovered from the quarry, two of which have the epiphysis attached, and appear to have belonged with the type, or an

animal of equal age. One of these, (text-fig. 2B) is essentially complete, and is of the right side.

The third metacarpal of *A. pons* is about equal in length to that of *A. mexicanus* (Lance, 1950, p. 50, pl. 5), but is less slender. It is longer than the metacarpal of *A. somaliensis* (Stehlin & Graziosi, 1935, tav. 2, fig. 2) but of about equal diameter, and nearly equal in length, but less slender than that of *A. hemionus* (*ibid.*, fig. 3).

Metatarsal III.—One nearly complete metatarsal is preserved which belonged to an animal of similar age to that of the metacarpal described above. The distal epiphysis is completely ossified with no trace of the suture. The bone is less slender than those of *A. hemionus* and closely resembles those figured by Lance (*ibid.*, pl. 5) for *A. mexicanus*.

The metatarsal of *A. pons* closely resembles that of *A. somaliensis* (*ibid.*, fig. 1), but is a little larger. It is also slightly larger than that of *A. mexicanus* (Lance, 1950, p. 50, fig. 4), but otherwise similar.

Discussion.—The type and associated material of *Asinus pons* has, on the one hand, the morphological characters of the living African asses, and, on the other hand, is unmistakably related to *Asinus mexicanus* of middle Pliocene age [latest Hemphillian according to Lance (1950)]. The relationship between *A. mexicanus* and *A. pons* seems to be one of direct descent. This is indicated, not only by close morphological resemblance, but also by three special features, the style on the third deciduous upper premolar, the spur on the paralophid of DP_2 which tends to unite with the metaconid, and the spurs on the anterior borders of the protocones, all of which are shared by both species.

The question of the age of *A. pons* is much less easily determined. The permanent teeth are approximately 10 mm. higher crowned than are those of *A. mexicanus* which insures that *A. pons* belongs to a considerably later time. The material was found in association with remains of *Tanupolama* which Dr. Lance believes to belong to the

MEASUREMENTS OF *Asinus pons* QUINN, N. SP.
all measurements in mm.

U.A. no. 9-1, upper permanent dentition, (sectioned) type, text-fig. 1A

	AP	Tr	Pl	Pw	Cl
P^2	33.0	24.8	6.5	5.2	—
P^3	29.2	26.0	10.0	6.0	—
P^4	28.2	26.6	11.3	6.0	—
M^1	24.8	26.0	8.5	5.5	41 ±
M^2	25.0	25.3	10.0	6.0	52 ±
M^3	24.5	19.6	8.5	4.1	—

U.A. no. 9-1, upper deciduous dentition and first molar, type, text-fig. 1B

DP^2	37.5	22.3	8.2	6.5	10.5
DP^3	26.8	24.0	7.0	6.7	11.5
DP^4	28.5	24.0	8.9	6.5	15.0
M^1	31.0	24.0	10.5	5.4	71 ±
M^2*	28.7	24.5	12.0	—	78.5

U.A. no. 9-2, lower deciduous dentition, text-fig. 1C

	AP	Tr	MM	CL
DP_2	33.5	11.1	13.5	—
DP_3	30.2	9.8	13.7	—
DP_4	30.5	9.1	12.5	—

U.A. no. 9-3, right metacarpal, text-fig. 2B
Length 222 mm., proximal width 43.5 mm., mid-shaft 29 mm., distal width approximately 39 mm.

U.A. no. 9-4, right metatarsal, text-fig. 2A
Length 253 mm., proximal width 45.2 mm., mid-shaft 28.2 mm., distal width 45 mm.

* Measurements of unworn M^2 at the alveolus.

Blancan species. In addition, material of a marmot has been found in the same place which is also indicative of a Blancan form.

Although Pleistocene (Blancan) deposits as well as younger beds are known from this part of southern Arizona, Pliocene deposits have not been found. Also, the younger deposits all seem to be post-Wisconsin in age—containing artifacts and *Bison* remains. This certainly provides no assurance that *A. pons* belongs to early Pleistocene time, but it seems safe to assume, for this and other reasons, it does belong to Pleistocene and not an earlier time.

Late Pleistocene remains of *Asinus* were reported by Skinner (1942) from a cave near Patagonia, Arizona. *A. pons* does not resemble this animal closely, nor does it seem to belong to undescribed late Pleistocene species from Texas.

There is a possibility the Comose material belongs to *A. cumminsii* (Cope) described from the Blanco beds of Texas, but the type of *A. cumminsii* is too much worn to make definitive comparisons. According to Cope (1893, p. 67) the protocone of *A. cumminsii* is very short anteroposteriorly, which is true also of *A. pons*. He also says the protocone is not grooved internally, although both his figures (pl. 20, fig. 7 and pl. 23, fig. 1) show the area as missing, whereas the protocones of the molars of *A. pons* are somewhat grooved. Likewise, the teeth of *A. cumminsii* lack the pli caballin whereas it is present on all but the second premolar and third molar of *A. pons*. The occlusal surface of the type tooth of *A. cumminsii* agrees in size with those of *A. pons* but the first molar of *A. pons* is sectioned 41.5 mm. above the base whereas that of *A. cumminsii* is worn to a length of 33 mm. The type of *A. cumminsii* therefore may represent larger teeth. Material in the Bureau of Economic Geology collections, The University of Texas, found in the same beds as teeth of *Hippotigris simplicidens* (Cope) are smaller than those of *H. simplicidens* and larger than those of *A. pons*. The lower molar teeth have the shortened median valley, and it was on the basis of this material the species was referred to *Asinus* (Quinn, 1955, p. 52–53).

Comparisons were made, contrasting the crown height of teeth of *A. pons* with those of living species of *Asinus*, with negative results. Teeth of the available specimens in the Chicago Natural History Museum,[1] which supplied the data on the recent asses, were incompletely developed at the time the first and second premolars began to receive wear. It was thus not possible to determine the maximum hypsodonty of these teeth. The condition, according to Stirton (1947, p. 37), is more typical of later horses than earlier ones and would indicate *A. pons* is more primitive than the living asses, for the first and second molars appear to have been completely formed at the time of eruption.

The fact that teeth of *A. pons* are fully as hypsodont, or perhaps more so than those of the living asses could mean *A. pons* is a late rather than early Pleistocene form, or that it is more progressive than living *Asinus* in the development of hyposdonty. It seems certain *A. pons* is not ancestral to the living asses, and the development of the molars seems to indicate it is not a late Pleistocene form.

The chief interest of the new species is that, insofar as is now known, it represents the first recognized Pleistocene descendent of a Pliocene species of horse. The 10 mm. increment in hypsodonty cannot be accurately assessed with reference to absolute time, but it surely indicates a very considerable hiatus between late Hemphillian and Pleistocene, as much perhaps as ⅓ of the Pliocene epoch.

Stirton (1947, p. 38) mentioned a possible break in the faunal record between Hemphillian and Blancan time. Quinn (1955, facing p. 65) included the Blanco beds in the Pleistocene section and indicated the upper third of the Pliocene section to be blank. In the same paper (1955, p. 52–53) the late

[1] Chicago Natural History Museum (letter from B. Patterson).

1429. *A. a. somalicus* juv., Laperus, Br. Somaliland; all milk teeth in use; M_1^1 not yet through the gum, rootless, enamel deposition not ended. Height of M^1 at mesostyle 65.0+.

42715. *A. a. asinus*. $Di_{2-3}{}^{2-3}$, $dm_{3-4}{}^{2-4}$ in use; I_1^1 p_2^2 just through the gum; $M_{1-2}{}^{1-2}$ in use, root of M_1^1 not fully formed, of M_2^2 not formed; M_3^3 not yet through the gum. Height of M^1 at mesostyle 73.6+, of M^2 75.0+.

It would seem from this material that the roots do not form until after wear has begun so you cannot get the full height, but maybe your larger sample of burros includes some specimens in which this is possible.

Hemphillian horse *Pliohippus mexicanus* Lance was referred to *Asinus*.

A. pons appears to substantiate both conclusions. It surely is an *Asinus*, and there surely is a considerable hiatus represented by its increase in hypsodonty over *A. mexicanus*. So great is the indicated hiatus that even if the whole of the Pleistocene be included there would still be a considerable gap between Hemphillian and Blancan time.

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NOMENCLATURE OF PORIFERA, ESPECIALLY CONCERNING THE SO-CALLED "GLASS SPONGES" OR HYALOSPONGEA

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ABSTRACT—Hyalospongea is the preferable name for the glass sponges, and was established by Claus in 1872 with a sound diagnosis that properly ignored spicule shape. Its retention is in complete accordance with the Rules of Nomenclature, and accepted usage, although R. E. H. Reid disagrees with my views in the *Journal of of Paleontology* for January 1957. Reasons are given for the inadvisability of substituting the name Hexactinellida for the class, as Reid proposes. Hexactinellidae is a valid name, based on its oldest genus *Hexactinella*, whereas Reid terms it "invalid." A summary is given of the origins of the names of the phylum Porifera, and its classes.

INTRODUCTION

IN the *Journal of Paleontology*, v. 31, no. 1, January 1957, p. 282–286, R. E. H. Reid writes "On Hexactinellida, Hyalospongea, and the Classification of Siliceous Sponges." He discusses my section, which is in part E of the "Treatise on Invertebrate Paleontology," and criticizes the names which are there applied to the classes of Porifera. It may therefore be appropriate to explain further the background of this nomenclature with some detail which was editorially regarded as unnecessary in the obviously condensed structure of the "Treatise."

Sponges were well known to the ancient Greeks and were discussed by Aristotle, who wisely recognized that they are animals. In his writings he mentions several kinds, which appear to be varieties of macerated sponges such as those that are used in bathing and the arts. Then, as now, the "commercial" sponge was and is merely the cleaned fibrous skeleton of an aspiculous sponge.

Modern taxonomy is based upon the epoch-making volumes by Linnaeus entitled "Systema Naturae" and in particular on the tenth or 1758 edition. In the volume on Vegetabilia, which appeared in 1759, Linnaeus described several species of sponges, but put all sponges in the single genus *Spongia*, type species *officinalis*, page 1348. It may be noted that in his twelfth edition (1767) Linnaeus finally realized the animal nature of sponges.

The diversity of sponges clearly called for more than the single genus, but fifty-five years elapsed before additional genera were erected. In 1814 Oken discussed sponges, dividing them into sixteen genera. He seems to have had no specimens nor much experience with actual sponge animals; he probably had several varieties of commercial sponge, and he certainly studied the writings of Linnaeus and other eighteenth century writers. His genera are vaguely described; most of them have not since been used, and all of them stand as taxonomic hazards. For example, the name "Ephydatia" is today widely used by students of fresh-water sponges, whereas this name, coined by Lamouroux, 1815, p. 2, was erected precisely and definitely for exactly that which Oken called *Tupha*. Actually the freshwater sponge in question is properly named *Meyenia*.

Lamarck also had been observing the need for more than a single genus; and, in 1815, he established three well defined genera, all of which passed at once into active usage. These were *Spongilla*, for the commoner freshwater sponges, also *Geodia* and *Tethya* for certain marine sponges.

As soon as the group was divided into genera, need arose for a comprehensive name. The first one proposed appears to be CERATOPHYTA of von Schweigger, 1820. If the rules of priority applied above the generic level, this would have to be the name of the phylum. It has not been used by subsequent authors, however. A sequence of names occurred instead, of which the principal ones are as follows:

* To our regret we have been informed that Dr. M. W. de Laubenfels died early in February of this year.—Editors

SPONGIDIAE Gray, 1821,
POROPHORA Grant, 1825,
SPONGIARIA Nardo, 1833,
PORIPHERA Grant, 1841,
SPONGIAE Hogg, 1841, and
PORIFERA Grant, 1861.

The latter two have been the ones most employed, and usage has predominantly settled upon the latter.

In the early nineteenth century, invertebrates in general and sponges in particular were more and more studied; and, by 1860, so many sponge genera had been recognized that a felt need existed; the group required subdivisions.

In 1862 Oscar Schmidt treated sponges as an order and divided them into six families as follows:

1. CALCISPONGIAE, with calcareous skeletons;
2. CERAOSPONGIAE, with only spongin skeletons;
3. HALICHONDRIAE, the common sponges;
4. CORTICATAE, with conspicuous cortex;
5. HALISARCINAE }
6. GUMMINEAE }
   for sponges with only jelly or slime skeletons. There is no discernible difference between these two as he first established them and Schmidt himself promptly amalgamated the two but used sometimes one name, sometimes the other.

Other systems appeared in the years that followed but were promptly ignored because they were absurd, or unintelligible, or because they differed only slightly from the systems that are here discussed. As a typical example, one may notice the division of all sponges into "Perforantes" and "Imperforantes" by Duchassaing & Michelotti, 1864.

The next system that attracted (and deserved) attention was that of Bowerbank in 1864. He treated the sponges as a class and divided them into three orders. These were:

1. CALCAREA, with calcareous skeletons;
2. SILICEA, with siliceous skeletons; and
3. KERATOSA, with no mineral skeletons.

In 1870 Oscar Schmidt added two more families to the half-dozen of his 1862 taxonomy. These were:

7. HEXACTINELLIDAE, and
8. LITHISTIDAE.

In 1872 Haeckel used Bowerbank's three groups but returned to the earlier spelling CALCISPONGIAE, and to maintain harmony, he used SILICISPONGIAE and CERATOSPONGIAE. He added MYXOSPONGIAE for the slime sponges and sometimes he also used the word FIBROSPONGIAE for all sponges except the slime sponges. His whole work, down to species, is characterized by similar bewildering inconsistencies. He generally divided the CALCISPONGIAE into families that he called Ascones, Syncones, and Leucones; but, from time to time, in the same treatise, he divided them instead into Monograntiae and Polygrantiae. He commonly established two or more genera for a single species or specimen.

In 1866 appeared the first edition of Carl Claus "Grundzüge der Zoologie." He regarded the sponges as a class of Protozoa and gave it synonymous names, Spongiae and Porifera (page 48). He divided it at once into six families:

1. CALICOSPONGIAE,
2. CERAOSPONGIAE,
3. GUMMINEAE,
4. CORTICATAE,
5. HALICHONDRIAE, and
6. HALISARCINAE.

The second edition of this work bears the date 1872 on the title page, but may not have actually appeared until 1873. Here he puts the "Spongiae–Porifera" as a class of the Coelenterata, and divides it into seven "Groups." These correspond to his six families of 1868 with the following exceptions: There are spelling changes to CALCISPONGIAE and CERASPONGIAE, and he adds the HYALOSPONGIAE, as discovered by Reid.

Zittel, in 1878, in his masterly work on paleontology regarded the Porifera as a class, divided into the following orders:

1. CALCISPONGIAE,
2. MYXOSPONGIAE,
3. CERAOSPONGIAE,
4. LITHISTIDAE,
5. MONACTINELLIDAE,
6. TETRACTINELLIDAE, and
7. HEXACTINELLIDAE.

Vosmaer prepared an excellent monograph of the sponges for Brown's "Klassen und Ordnungen des Thierreichs." It as published in five sections from 1882 to 1886. He divided the sponges into two classes in the 1885 section. These were:

CALCAREA, and
NONCALCAREA.

The latter he had in three orders:

1. CONACUSPONGIAE, with spongin;
2. SPICULISPONGIAE, all that lack spongin, except
3. HYALOSPONGIAE, the glass sponges.

Vosmaer wrote as though originating the name "HYALOSPONGIAE," and I believe he was not copying anyone. He also conducted a colossal study of sponge literature culminating in his volume "The Bibliography of Sponges" with some 3,823 entries. The fact that he does not there list "Claus 1872" almost certainly indicates that he was not aware of "Claus 1872," as Reid was. The latter author is correct in stating that Claus in the 1872 edition of his textbook of General Zoology did use the name HYALOSPONGEA for the glass sponges.

In 1885 Sollas also classified the sponges, first in two classes corresponding to those of Vosmaer, but named CALCISPONGIAE and PLETHOSPONGIAE. The latter was divided into subclasses called:

1. MYXNOSPONGIAE, the slime sponges,
2. DEMOSPONGIAE, all the others except,
3. HEXACTINELLIDA, the glass sponges.

In 1900 Minchin monographed the Porifera for "Lankester's Treatise on Zoology." He put them in three classes as follows:

1. CALCAREA, or CALCISPONGIAE,
2. DEMOSPONGIAE, for all the rest except the glass sponges, and
3. HEXACTINELLIDA, or HYALOSPONGIAE.

This grouping has been almost unanimously followed ever since, with variance only in the choice of synonyms. This matter of choice now warrants consideration.

Priority is positively not required for class names. Instead they should be appropriate. What is appropriate? The best names are significant, descriptive and harmonious.

SPONGIAE and PORIFERA are the two most used, most appropriate names that have been suggested for the phylum. The name PORIFERA has been preferred, but this leaves the word "SPONGIAE" available for other suitable employment.

The name DEMOSPONGIAE or DEMOSPONGEA is practically unchallenged. It conveys to the reader the proper realization that sponges are designated, in this case, the "common" sponges.

CALCISPONGIAE (or CALCISPONGEA) and CALCAREA stand as synonyms between which a choice must be made. CALCAREA was erected as a match or complement to Silicea, and should be dropped as Silicea has been dropped. The term CALCISPONGEA, like DEMOSPONGEA, reveals that sponges are the animals being discussed.

HYALOSPONGIAE (or HYALOSPONGEA) and HEXACTINELLIDA also stand as synonyms between which a choice must be made. The term HEXACTINELLIDEA has several defects.

First, as it is spelled, it has the form of name that is preferred for orders. Many zoologists now feel that all order names should end in the letters "ida": I agree.

Second, it bears so close a resemblance to the family name Hexactinellidae that it therefore is less suitable (although permissible) as a class name.

Third, it implies that the diagnosis of its members hinges upon the hexactinellid spicule; I believe this criterion to be improper, that members of the class in question may lack hexacts, and that hexacts may occur in other classes. The impropriety of the hexact criterion is to be discussed below.

The name HYALOSPONGEA (or HYALOSPONGIAE) is harmonious; in my opinion this is the chief reason for selecting it in preference to HEXACTINELLIDA. Many taxonomists undervalue harmonious names, because in their work harmony serves no great use. They are so familiar with the groups of their specialization that disharmonious names do not annoy them; their chief need is freedom from change.

My approach is profoundly affected by experience that many taxonomists do not enjoy, or suffer, as the case may be. For a third of a century I have been teaching large classes of students of beginning zoology. Does not this larger audience of students deserve more consideration, when a choice must be made, than the very small audience of specialists? The name HYALOSPONGEA matches DEMOSPONGEA and CALCISPONGEA in a way that is helpful to beginners. It makes quickly evident the fact that sponges are involved. One can talk or write about hyalosponges, as well as calcisponges and demosponges.

We can choose, we must choose, and both names are completely available. I hope that

zoologists, in view of the considerations mentioned above, may see fit to choose the name HYALOSPONGEA.

The impropriety of employing hexacts as a criterion for the class HYALOSPONGEA was mentioned above, and wants further discussion.

Bidder's classification of sponges was not mentioned above, but it is one that deserves very careful attention. This extremely astute zoologist wrote on the subject in 1929, arranging all sponges in two PHYLA (not just classes) as follows:

> 1. GELATINOSA, for calcisponges and demosponges, because both of these are characterized by sponges whose bodies are permeated extensively by mucoid colloids or mesogloea.
> 2. NUDA, for the glass sponges, because their bodies lack these intercellular jellies.

Bidder maintained that these two phyla could not have had a common ancestor, but that they evolved from two separate groups of Protozoa. I would not agree with this last, and do not use the taxa NUDA and GELATINOSA, but before we dismiss these concepts let us notice a most important fact:

Burton, the very eminent British spongologist, endorsed Bidder's classification! In Burton's 1934 treatise on Antarctic Sponges he began using it, employing the taxa "Phylum GELATINOSA" and "Phylum NUDA."

The impropriety of employing hexacts as a criterion for the class HYALOSPONGEA was shown in my classification, as used in the above-mentioned "Treatise on Invertebrate Paleontology." There it was clear that the glass sponges included more than Schmidt's Hexactinellidae, and that the taxon HYALOSPONGEA was not identical with, but instead was more inclusive than the group HEXACTINELLIDA as conceived by Schulze, and others. I included the order HETERACTINIDA, which in turn comprises taxa sometimes called HETERACTINELLIDA and OCTACTINELLIDA.

Reid has made excellent studies of the HETERACTINIDA, and offers some stimulating and valuable suggestions about them. He points out some reasons for assuming that heteractinellids and octactinellids are rather distinctly related to hexactinellids, and would erect subclasses for them. We are not in great disagreement; although I should think they might stand as orders of HYALOSPONGEA, rather than subclasses.

The impropriety of employing hexacts as a criterion for the class HYALOSPONGEA was shown by Claus when he established the name. Reid emphasizes this christening in connection with pointing out that it was earlier than Vosmaer's naming, which I had quoted. Reid quotes Claus literally, but in the original German. A translation thereof into English is here appropriate. Claus said:

> "With a coherent scaffolding of silica that has a history of having been free siliceous bodies, later cemented into a fibro-reticulation by silica; often with tufts of long siliceous hairs as a basis of attachment."

Claus did well to diagnose the class HYALOSPONGEA as he did. All glass sponges, as they mature, have a cementing process whereby their originally discrete siliceous spicules are conjoined into a rigid framework. This process may begin in the postlarval stage, or not until a size of many centimeters measurement, but is always significantly present. Those demosponges that have siliceous skeletons may in a few cases acquire inorganic rigidity, but if so, they come to this state by a deposition of silica on spicules until these become the elaborate, grotesque "desmas" that interlock.

The glass sponges employ silica to conjoin spicules in exactly the same way that demosponges employ sponging to conjoin spicules.

The glass sponges not only lack spongin, but, as Bidder pointed out, they lack mesogloea or mucoid skeletal substance.

The glass sponges have very distinctive architecture. In all other sponges the flagellate chambers are so arranged that they are responsible for all, or nearly all, of the internal transport. The intake and output of water, the whole circulation, depends upon their activity. In HYALOSPONGEA this is not the case. The glass sponges are so "OPENWORK" that environmental currents may sweep through them freely. Is this a "labor-saving" device?

I will hazard a guess that future research may demonstrate a further great difference between the HYALOSPONGEA and all others; that whereas glass sponges certainly contain no vegetable symbionts, it may be charac-

teristic of other sponges that they do. This implies the suggestion that some common intracellular inclusions may be greatly modified obligatory vegetable symbionts.

All known Recent glass sponges have at least some hexactinellid spicules, but I would not be astonished tomorrow to discover a new one that did not have any such, and would be prepared to classify it as HYALOSPONGEA for the other above-mentioned critieria. I have given it as my considered opinion that certain fossil genera (*Leptomitus, Halichondrites, Lasiothrix*) were Hyalospongea, although only monaxon spicules have been found in them. I believe the hexact spicule is primitive; these spicules appear in the earliest Cambrian fossils. Monaxon spicules may be derived from hexacts by simplification.

In conclusion, we may note some items in Reid's critique other than the primary matter of the preferable name for the class HYALOSPONGEA.

Reid states that Hexactinellidae "cannot be used as a family group name." It most certainly can be so used, being the appropriate name of the family which has as its oldest genus the genus *Hexactinella* Carter.

Reid further states that Hexactinellidae is used "invalidly" by me "for the family whose valid name is Tretodictyidae." *Hexactinella* is the oldest genus in this family, and Hexactinellidae is the oldest name for the family. F. E. Schulze in 1886 proposed changing the family name to Tretodictyidae and was regrettably followed by Ijima in 1927, doubtless noticed by Reid. Yet, Schulze, in 1887, page 328, correctly retracted his step of setting up a family based upon the genus *Tretodictyum*, and even went so far as to drop that genus in synonymy to *Hexactinella*. I would not go quite so far, but retain *Tretodictyum* because of its possession of discohexasters. It is not suitable, however, as the type of a family because it is a questionable or dubious genus.

Finally, I would like to express great sympathy with one point made by Reid. He referred to the great dependence which paleontologists must of necessity put upon skeletal structures such as spicules. Sometimes we are thus forced to use classifications that are somewhat artificial. I have employed the "order" LITHISTIDA in spite of the fact that some evidence points toward a polyphyletic origin for the various lithistid sponges. Ijima, perhaps wisely, divided the glass sponges into orders based upon microsclere content; and microscleres are rarely found in fossils, therefore many of us, when dealing with fossils use a classification that ignores microscleres. Yet, to use the presence of hexact spicules (properly) as a recognition mark for glass sponges does not require that we name the class for these spicules. There are excellent reasons for retaining the name that Claus gave them—HYALOSPONGEA.

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ARCHAEOCYATHID LOCALITIES IN WASHINGTON, BRITISH COLUMBIA, AND THE YUKON TERRITORY

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ABSTRACT—The occurrences of archaeocyathids in the northern part of the Cordillera are given with their related lithologic unit where possible: (1) Colville, Washington—Old Dominion limestone; (2) Salmo, B. C.—lower part of the Laib group; (3) Dogtooth Range, B. C.—Donald formation; (4) Quesnel Lake, B. C.—Cariboo series; (5) Sinclair Mills, B. C.; (6) Pine Pass, B. C.—Misinchinka schists; (7) Aiken Lake, B. C.—upper Wolverine complex; (8) McDame Creek, B. C.—Atan group; (9) Wolf Lake, Yukon Territory—Lord's group B and C units; and (10) Quiet Lake, Yukon Territory.

It is believed that these occurrences outline the western edge of the geosyncline present in this region in Lower Cambrian time.

INTRODUCTION

THE senior author has presented a paper to the Paleontological Society at its Los Angeles meeting in 1954, outlining the distribution of Archaeocyatha in British Columbia. Additional information has come to light since, and the junior author was able to incorporate it in the present paper as well as a fuller discussion of correlation problems posed by the Lower Cambrian rocks in the Cordilleran region. A rather completely bibliography is attached to the paper to facilitate comparisons between Cordilleran archaeocyathid faunas with those found in Europe, Asia, and Australia.

Archaeocyathids are known to occur at ten localities from Washington to the Yukon in the North American Cordillera. In nearly every locality they are found in relatively pure limestones which indicate their preference for environment in clear shallow marine seas. The Lower Cambrian sea of Western North America is thought to have been geosynclinal in nature. The archaeocyathids appear to be restricted to the western shore of this geosyncline, since none have been yet reported from its eastern limits.

The ten archaeocyathid localities are:

(1) Colville, Washington—Old Dominion limestone;
(2) Salmo River, B.C.—lower part of the Laib group;
(3) Dogtooth Range, B.C.—Donald formation;
(4) Quesnel Lake, Turk's Nose, B.C.—Cariboo Series;
(5) Sinclair Mills, B.C.;
(6) Pine Pass, B.C.—Misinchinka schists;
(7) Aiken Lake, Osilinka Valley, B.C.—upper group of the Wolverine Complex;
(8) McDame Creek, B.C.—Atan group;
(9) Wolf Lake, Yukon—Lord's (1944) Group B and Group C sediments; and
(10) Quiet Lake, Yukon.

COLVILLE, WASHINGTON

The archaeocyathids of the Colville area were collected from a west-facing bluff of Old Dominion limestone, about 1 mile north of the village of Colville (Little, 1950). Because of the extensive faulting that has occurred in this area, this outcrop of Old Dominion limestone could not be located relative to the underlying Addy quartzite or to any other stratigraphic horizon.

Faunal List from Colville Locality

Ajacicyathus nevadensis	xx
A. rimouski	xx
Ethmophyllum whitneyi	x
E. americanum	o
Archaeocyathus atlanticus	xxx
A. borealis	o
Archaeopharetra typica	x
Pycnoidocyathus amourensis	x
P. columbianus	x
P. n. sp.	o
Claruscyathus solidus	xxx
Protopharetra dunbari	xx
P. sp.	xxx
Dendrocyathus sp.	o
Syringocnema colvillensis n. sp.	o
Monocyathus sp.	o

Key: rare—o, few—x, common—xx, abundant—xxx.

This archaeocyathid fauna is unique in abundant specimens of *Archaeocyathus atlanticus*, *Protopharetra* sp., and *Claruscyathus solidus*. These species resemble one another in possessing relatively poorly organized skeletal structures. They cannot be considered as very primitive forms, however, since some degree of organization is present in the development of an inner wall and central cavity. Comparison of these species with *Ethmophyllum whitneyi* emphasizes their inferior organization and suggests that they may be early forms in the evolution of Archaeocyatha. Thus, the impression is received that the Old Dominion of the Colville area, is in part at least, low or middle Lower Cambrian in age. This impression is further borne out by the work of Zhuravleva and Zelenov (1955). They report that the lower "bioherms" of the Lower Cambrian of Russia are characterized by the genera *Archaeocyathus*, *Monocyathus*, and *Ajacicyathus*, all of which are present in the collection from the Colville locality.

A further indication of the approximate position in the Lower Cambrian of this archaeocyathid zone is afforded by fossil evidence from the underlying Addy quartzite formation. This formation was discovered to be fossiliferous in 1949 and the following species have been since identified (Okulitch, 1951):

Micromitra (*Paterina*) sp.
Kutorgina cf. *cingulata* (Billings)
Kutorgina sp.
Rustella cf. *edsoni* Walcott
Hyolithellus sp.
Nevadia addyensis Okulitch

In regard to this last species, Okulitch states that "the presence of the rare genus *Nevadia*, with its very primitive characteristics, suggests the lower portion of the Lower Cambrian."

From the above evidence it can be tentatively concluded that the archaeocyathid zone of the Old Dominion limestone is early Lower Cambrian in age. It may now be possible to compare other archaeocyathid collections with that of the Old Dominion and to suggest their probable stratigraphic positions in the Lower Cambrian.

SALMO, B.C.

In the eastern part of the Salmo map area there is a long narrow band of limestone that comprises the basal unit of the Laib group. The band trends almost due north, (lat. N 49° 00′, long. 117° 08′) and extends from the International Boundary to a point five miles north. In 1948 Dr. Little discovered archaeocyathids in the limestone band. Collections were made from two or more localities in the limestone unit.

The collection of archaeocyathids from the area studied by the junior author was contained in a greenish-grey, fine-grained limestone. The list appearing in Dr. Little's report is a compilation of *all* the archaeocyathids identified by Okulitch from the limestone band. This explains the variation between the two faunal lists given below:

Faunal Lists from the Salmo Locality

	Little, 1950	*Greggs, 1957*
Ajacicyathus nevadensis	x	x
A. undulatus	x	
A. purcellensis	x	
Ethymophyllum whitneyi	xxx	xxx
E. americanum	xx	xx
E. sp.	x	
Coscinocyathus dentocanis	o	
C. sp.	o	
C. cf. *miniporosus*	o	
Archaeocyathus atlanticus	x	x
Pycnoidocyathus amourensis	x	x
P. columbianus	o	
P. donaldi	o	
P. sp.		
Copleicyathus ? laminosus	o	
Claruscyathus obliquus	o	
Protopharetra sp.	x	x
Archaeocyathellus sp.	o	o
Paracoscinus sp.	o	
Syringocyathus canadensis		o
Protopharetra sp.		x
P. dunbari		x
Archaeocyathellus sp.		o

Rare—o, few—x, common—xx, abundant—xxx.

The dominant genus in this archaeocyathid zone of the Laib group is *Ethmophyllum*, particularly the species *E. whitneyi*. This species is present in limited numbers in the archaeocyathid zone of the Old Dominion. Thus the position of *E. whitneyi* in the Laib supplants that occupied by *Claruscyathus solidus*, *Archaeocyathus atlanticus*, and *Protopharetra* sp. in the Old Dominion. The faunal differences between these lithologic units are: the presence of *Archaeocyathus borealis*, *Archaeopharetra typica*, *Pycnoidocyathus* sp., *Archaeosycon* sp., *Claruscyathus solidus*, *Dendrocyathus* sp., *Syringocnema colvillensis*, and *Monocyathus* sp. in the Old Dominion and their absence in the Laib group; and the presence of *Ajacicyathus undulatus*, *A. purcellensis*, *Coscinocyathus dentocanis*, *C.* sp., *C.* cf. *miniporosus*, *Pycnoidocyathus donaldi*, *P.* sp., *Copleicyathus* (?) *laminosus*, *Claruscyathus obliquus*, *Archaeocyathellus* sp., and *Paracoscinus* sp. in the Laib group and their absence in the Old Dominion.

If only the viarations in the frequencies of *Ethmophyllum whitneyi*, *Claruscyathus solidus*, *Archaeocyathus atlanticus*, and *Protopharetra* sp. are considered, the faunal differences are still marked. These faunal differences may be ecological in nature. At present, little is known of the ecology of Archaeocyatha. Their restriction to limestones indicates a preference for a marine environment of moderately shallow clear water, but the ecological requirements of particular species are unknown. The faunal differences between the Laib and the Old Dominion may be due to ecology. It would seem more probable, however, from the limited information available that different archaeocyathid zones are being correlated. The zones may be stratigraphically only several hundred feet apart. Because of the presence of *Coscinocyathus dentocanis*, *C.* cf. *miniporosus*, *Archaeocyathellus* sp., *Paracoscinus* sp., and abundant *Ethmophyllum whitneyi* in the basal Laib, it is suggested that the base of the Laib might be correlated with some horizon stratigraphically above the archaeocyathid zone of the Old Dominion limestone. How far above cannot be determined, since neither the stratigraphic position of the Old Dominion archaeocyathid zone nor the stratigraphic interval between the two archaeocyathid zones, Colville and Salmo, are known.

DOGTOOTH MOUNTAINS, B.C.

The archaeocyathids from the Dogtooth Mountains were collected from the Donald formation where the latter outcrops in the canyons of Holt and Canyon Creeks. The specimens were systematically collected (Okulitch, 1948) and located with reference to Evans' stratigraphic section of the Donald formation (Evans, 1932).

Faunal List from the Donald Formation

Ajacicyathus nevadensis	x
A. purcellensis	xx
A. undulatus	x
Coscinocyathus dentocanis	o
C. rhyacoensis	o
C. sp.	o
Archaeocyathus atlanticus	x
A. taeniatus	o
Copleicyathus (?) *laminosus*	o
Pycnoidocyathus donaldi	x
P. columbianus	xx
P. septimus	x
P. sp.	o
Archaeosycon evansi	o
Claruscyathus obliquus	o
Pycnoidocoscinus rectiporus	o

Rare—o, few—x, common—xx, abundant—xxx.

The specimens representing four of the species, *Coscinocyathus dentocanis*, *C. rhyacoensis*, *C.* sp., and *Pycnoidocyathus columbianus* were collected by C. Evans in 1928. The remainder were collected by Okulitch in 1946. All the specimens, except those collected by C. S. Evans, are stratigraphically located with reference to the Donald–St. Piran contact. *Claruscyathus solidus* is the lowest specimen, stratigraphically, occurring in Evans' Bed 2, 25 feet to 175 feet above the base of the Donald formation. *Ajacicyathus nevadensis*, *A. purcellensis*, *A. undulatus*, *Archaeocyathus atlanticus*, *A. taeniatus*, *Copleicyathus* (?) *laminosus*, *Pycnoidocyathus* sp., *Archaeosycon evansi*, and *Pycnoidocoscinus rectiporus* occur in Bed 5 of the Donald formation, 330′ to 370′ above the St. Piran contact. *Pycnoidocyathus septimus* from Bed 7 is the highest reported species. This faunal suite is remarkable for its abundant species of *Ajacicyathus*, *Coscinocyathus*, and *Pycnoidocyathus*, and for the absence of *Ethmophyllum* species.

From previous stratigraphic studies the Donald formation is considered to be Lower

Cambrian in age and is directly overlain by the Middle Cambrian Canyon Creek formation. The stratigraphic position of the Donald has been established on paleontological evidence other than that of archaeocyathids, i.e., *Kutorgina*, *Olenellus*, *Dorypyge*, *Rustella*, etc. On the evidence afforded by these genera it is possible to establish the archaeocyathids of the Donald as late Lower Cambrian in age. The upper part of the Laib group and the Donald formation are correlated at present, and so it is relatively certain that the Donald archaeocyathid fauna is younger than the Laib fauna.

The absence of *Coscinocyathus*, *Pycnoidocoscinus*, and a more abundant *Pycnoidocyathus* assemblage in the Donald constitute the main differences between the faunas of these two lithologic units. The Laib archaeocyathid fauna contains numerous *Ethmophyllum*, and *Pycnoidocyathus amourensis*, *Archaeocyathellus* sp., and *Paracoscinus* sp. not present in the Donald formation. It is possible that *Coscinocyathus*, *Pycnoidocoscinus*, and abundant *Pycnoidocyathus* species are characteristic Archaeocyatha of of late Lower Cambrian.

SINCLAIR MILLS, B.C.

The Sinclair Mills locality is situated on the Upper Frazer River. The fossiliferous outcrop is approximately 4 miles upstream, i.e., southeast, from Sinclair Mills, and 600 feet southwest of the southwest bank of the Fraser River.

A small number of well-preserved archaeocyathids were collected from this area by Dr. K. D. Watson in the summer of 1950. The specimens are preserved in a light grey, fine-grained limestone.

The following species have been identified from the Sinclair Mills Archaeocyathid collection:

Ajacicyathus ajax
A. nevadensis
Ethmophyllum whitneyi
Coscinocyathus dentocanis
C. sp.
Pycnoidocyathus cf. *donaldi*
P. sp.
Protopharetra sp.
Archaeofungia sp.

This archaeocyathid fauna has not been studied in any detail, but it bears some similarity to the Donald fauna. The following species are common to both faunae: *Protopharetra* sp., *Pycnoidocyathus* cf. *donaldi*, *Coscinocyathus dentocanis*, and *Ethmophyllum whitneyi*. *Archaeosycon* sp. and *Ajacicyathus ajax* are found only in the Sinclair Mills fauna. In most respects, however, the Sinclair Mills fauna resembles that contained in Bed 5 of the Donald formation. It is probable, then, that the Sinclair Mills fauna is stratigraphically high in the Lower Cambrian succession.

QUESNEL LAKE AND PINE PASS, B.C.

These archaeocyathid localities are considered together because very little is known of either. In the Quesnel Lake area, archaeocyathids are known to occur in Lower Cambrian rocks that outcrop on the southeast slope of Turk's Nose Mountain, at the bend of the Cariboo River, between Sandy Lake and Spectacles Lake. These outcrops of the Cariboo Series are located just below fossiliferous Middle Cambrian strata. No species have been described from these outcrops.

The specimens from the Pine Pass area were so poorly preserved that it was possible to state only that they were Archaeocyatha. The specimens were found in an outcrop of badly sheared Misinchinka schists. The fossiliferous outcrop is located at a low elevation in the valley of the Misinchinka Creek, west of Pine Pass.

AIKEN LAKE, B.C.

The archaeocyathids of the Aiken Lake area occur in a small limestone lens in the upper portion of the Wolverine Complex. The locality is at lat. N 56° 09′, long. 125° 07′ W. This Complex is lithologically similar to and is probably a north-west exten-

Faunal List from Aiken Lake Area

Ajacicyathus purcellensis	xx
A. cf. purcellensis	o
A. clarus	o
A. osilinka	o
Coscinocyathus sp.	o
Archaeocyathus cf. *atlanticus*	o
Protopharetra rootsi	o
P. sp.	o
Pycnoidocyathus sp.	o
Dendrocyathus unexpectans	o

Rare—o, few—x, common—xx, abundant—xxx.

sion of the belt of "Proterozoic" rocks of the Cariboo district. The outcrop containing the archaeocyathids is located approximately six miles north of Wasi Lake near the Osilinka River. The specimens from this locality were collected by F. Roots in 1946.

This fauna does not appear to have any close affinity with other archaeocyathid faunas of the Lower Cambrian. Certain similarities to the Colville fauna are apparent in the presence of *Archaeocyathus* cf. *atlanticus*, *Protopharetra* sp., and *Dendrocyathus* sp. in both faunas. The Aiken Lake fauna is also similar to that of the Donald, since *Coscinocyathus* sp., *Pycnoidocyathus* sp., and *Ajacicyathus purcellensis* are common to both. Thus the Aiken Lake fauna may occur stratigraphically between the Colville and Salmo archaeocyathid zones, but no definite correlation is possible.

McDAME AREA, B.C.

The archaeocyathids from this area were collected by Dr. H. Gabrielse during the summers from 1950 to 1953. The locality is given as McDame Creek, near headwaters of French River, a tributary to Dease River, lat. N59° 20′, long. 129° 25′ W. Collections were made at nine separate localities from the Lower Cambrian limestones of the Atan group (Gabrielse, 1954). These collections may be from one general zone, but no stratigraphic date to determine this is available.

Faunal List from the McDame Area

Ajacicyathus nevadensis	o
Ajacicyathus undulatus	x
Ethmophyllum sp.	o
Ethmophyllum cf. *ratam*	x
Thalamocyathus sp.	o
Coscinocyathus dentocanis	xxx
C. sp.	xx
Archaeocyathus atlanticus	x
A. cf. *latus*	o
A. loculiformis	o
A. borealis	o
Archaeopharetra sp.	x
Pycnoidocyathus amourensis	x
P. columbianus	xx
Archaeofungia obliqua	o
A. sp.	o
Metacoscinus gabrielensis	o
M. deasensis	x
Archaeosycon sp.	o
Syringocyathus canadensis	o

Rare—o, few—x, common—xx, abundant—xxx.

This fauna, assuming it to be from one zone, has remarkable similarities to the Donald fauna of the Purcell Range. Species common to both are: *Ajacicyathus nevadensis*, *Ajacicyathus undulatus*, *Coscinocyathus dentocanis*, *C.* sp., *Archaeocyathus atlanticus*, *Pycnoidocyathus columbianus*, and *Archaeosycon* sp. The *Coscinocyathus* species are the most abundant in the McDame fauna, whereas the *Pycnoidocyathus* species predominate in the Donald fauna.

Since the Atan group is assigned a Lower and Middle Cambrian age, and no correlation with it and other Cambrian formations has yet been attempted, no adequate correlation of its archaeocyathid fauna can be made. It is suggested, however, that the archaeocyathid zone of the Atan group may be correlative with that of the Donald.

WOLF LAKE, YUKON TERRITORY

Archaeocyathids, comprising four separate collections, were collected from two localities in the Wolf Lake area. These were collected by Mr. W. H. Poole in 1955 from Lord's group B and group C sediments. The fossiliferous outcrops occur south of Rancheria River in the southeastern corner of the map area (Poole, 1955). No stratigraphic information is available for the various collections and the species listed below are grouped according to their occurrence in Lord's group B or group C sediments.

Faunal List from Wolf Lake Area

Group B sediments

Coscinocyathus tubicornis	o
C. sp.	o
Pycnoidocyathus amourensis	o
P. occidentalis	xx

Group C sediments

Ajacicyathus purcellensis	xx
Ajacicyathus yukonensis	o
Coscinocyathus dentocanis	xxx
C. multiporosus	o
C. cassiarensis	x
C. veronicus	o
Carinacyathus perforatus	x
Archaeocyathus atlanticus	o
A. sp.	o
Pycnoidocyathus solidus	o
Loculiformis ellipticus	xx
Metacocscinus poolensis	x

Rare—o, few—x, common—xx, abundant—xxx.

The preponderance of *Coscinocyathus* species, and to a lesser extent, *Pycnoidocyathus* suggests an affinity between the Wolf Lake fauna and that of the Donald. This relation indicates a later Lower Cambrian age for the archaeocyathids of the Wolf Lake occurrence.

QUIET LAKE, YUKON TERRITORY

A small collection of archaeocyathids was made from Lower Cambrian strata of this area in 1955 by Dr. Aho and Mr. Padgham. These fossiliferous strata outcrop on a ridge "which separates the head waters of the White Creek and Ketza River in the Pelly Mountains—" (Kawaze, 1956). More precisely, "the fossil locality is approximately 1000′ northwest from the northwest corner of the Kay No. 31 claim" (Kawaze, 1956). Mr. Padgham (personal communication) reports that two or more archaeocyathid zones are present in the area. The upper (?) zone occurs in a massive limestone, the lower, in a calcareous, shaly rock. The fossils in this latter zone are very numerous, well-preserved and easily collected.

Faunal List from the Quiet Lake Area

Ethmocoscinus (?) sp.	o
Coscinocyathus inequivallus	xx
C. serratus	o
Pycnoidocyathus columbianus	x
P. cf. *dissepimentalis*	x
Metacoscinus sp.	o
Claruscyathus ketzaensis	xx

Rare—o, few—x, common—xx, abundant—xxx.

The fauna is very similar to those of the Wolf Lake and Dogtooth Range. The presence of the genus *Claruscyathus* is suggestive of the lower part of the Donald formation, but the *Coscinocyathus–Pycnoidocyathus* assemblage is more typical of the stratigraphically higher archaeocyathid zone in Bed 5 of the Donald. The Quiet Lake fauna is probably late Lower Cambrian in age.

CONCLUSIONS

From the preceding descriptions of the archaeocyathid localities, their faunas, and their known stratigraphic positions, several conclusions are possible. It must be emphasized, however, that any conclusions are necessarily tentative, since the stratigraphic evidence on which they are based lacks detail or is otherwise incomplete.

The archaeocyathid zone of the Old Dominion limestone of the Colville area appears to be stratigraphically lower than that of the Laib group. The Laib fauna may be stratigraphically lower than any of the archaeocyathid zones north of the Salmo area, i.e., Dogtooth, Sinclair Mills, Aiken Lake, etc. Thus the middle (or lower) Lower Cambrian zones are characterized by abundant specimens of *Archaeocyathus atlanticus*, *Protopharetra* sp., and *Claruscyathus solidus*. The next stratigraphically higher zone is marked by numerous species of *Ethmophyllum*, and an absence of *Claruscyathus solidus*, *Archaeopharetra typica*, and *Monocyathus* sp. The highest Lower Cambrian archaeocyathid zone bears a fauna characterized by species of *Coscinocyathus* and *Pycnoidocyathus*.

It is worth noting at this point that there appears to be a trend for the known archaeocyathid zones to become higher stratigraphically within the Lower Cambrian from south to north. The significance of this trend has not been considered in this paper, and further study of these Lower Cambrian zones may show the trend to be due solely to insufficient stratigraphic data.

RECOMMENDATIONS FOR FURTHER STUDY

For satisfactory accurate correlation of the Lower Cambrian by Archaeocyatha, it is necessary to know precisely the horizons at which they occur, the type of occurrence, i.e., reef, lens, or bed. The collections should be sufficiently large to permit estimates of the relative abundance of the various species present. It is suggested that the recommendations given below be considered in the collection of archaeocyathids.

(1) Collections from separate zones be kept distinct, and stratigraphic intervals between the zones noted;
(2) Collections be accompanied by detailed lithologic descriptions of the enclosing sediments; and
(3) Collections should be referred to some known horizon, i.e. formation boundary, *Olenellus* zone etc.

It is appreciated that it is not always possible to follow the above suggestions in the field. Faulting, poor or discontinuous

outcrop, and a shortage of time all tend to prevent adequate collections of fossil material.

Further laboratory study of the phylum, if suitable collections were available, might result in the erection of several archaeocyathid zones. Ecological studies might also be profitably pursued to determine environmental controls of certain species, i.e., their tolerance to turbidity, depth of water required, etc. It is known that archaeocyathids preferred an environment that was unsuitable for trilobites. Where trilobites occur in the sediments, archaeocyathids are absent. Thus a system of zoning the Lower Cambrian on the basis of these two groups of animals would provide a method of correlation applicable to a variety of sedimentary facies.

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RECENT LITERATURE ON MESOZOIC AMMONITES

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THE period since about 1950 witnessed a remarkable renaissance of research and publication on ammonites, especially of the Mesozoic. Veterans in this field, such as Arkell, Collignon, Matsumoto, have been joined by new adepts, such as Benavides, Reyment, Zeiss, Westermann, and both groups have joined forces to produce a steady flow of new ammonitological monographs. Superimposed on, and crowning, as it were, this rich array of monographic work is the recently published "Part L—Mollusca 4—Cephalopoda—Ammonoidea" of the Treatise on Invertebrate Paleontology, covering both Paleozoic and Mesozoic ammonites.

The present review does not propose to adhere to any rigid time limits, nor can it in any way claim completeness. It is rather, of necessity, somewhat selective; the reviewer is well aware of the fact that he may favor certain papers of particular interest to himself and treat others, of equal scientific importance, more cursorily, or even omit them altogether.

As far as the Russian literature is concerned, such a perfunctory approach is forced upon the reviewer by his unfamiliarity with the language and the lack of translations of the papers concerned. Still, I should like to call attention to the excellent suture line drawings, other diagrams, and photographs which accompany Drużczic's (1956) work on Lower Cretaceous ammonites of the families Lytoceratidae, Tetragonitidae, and Phylloceratidae from the Crimea and the northern Caucasus. In addition to the genera *Biasaloceras* (Lytoceratidae) and *Euphylloceras* (Phylloceratidae), proposed in a preliminary paper (Drużczic, 1953) but not accepted in the Treatise, the new genus *Pseudotetragonites* (type: *P. kudrjavzevi* Drużczic) is here erected within the Lytoceratidae. This reviewer was particularly attracted to the chapter on the functional analysis of the ammonite shell, including a section on siphon, caecum, and prosiphon.

After having been diverted by the difficulties in dealing with Russian literature to a paper on Cretaceous ammonites, I should like to turn now first to the Triassic ones. In this field a quite recent monograph on Germanic* *Ceratites* by Rolf Wenger (1957) must be mentioned. It represents a complete revision of the genus *Ceratites* from which, however, the Alpine forms, such as the well known species *C. binodosus* and *C. trinodosus*, which are referred to *Paraceratites* instead, are excluded. The author's taxonomy of the genus *Ceratites* is based on the conception of the species as a total of individuals which corresponds to a part of a "phylogenetical branch" that can be delimited, on the strength of certain characters, from both older and younger parts of that branch. In thus circumscribing the species, Wenger, who is rather skeptical about purely morphological grouping, depends strictly on variation statistics; some 35 diagrams illustrating them constitute an essential portion of the monograph. This method enables him to hold the diagnoses and discussions of the several taxonomic units to a minimum. On the whole, Wenger's taxonomic approach may be credited with a considerable reduction of the extreme splitting that had been going on within *Ceratites* in the first half of this century. As compared to Schrammen's 11 subgenera of 1928 the author mentions only five, and the number of species is also greatly reduced; on the other hand, a considerable number of subspecies is established. The very rare "fastigate" *Ceratites*, in which the ribs cross the venter uninterruptedly (and among which, by the way, Rothe distinguished in 1949 seven species based on one individual each), are not granted taxonomic status but are interpreted as occasional mutants or as

* Meaning the Germanic, as distinct from the Alpine, facies of the European Triassic.

due to a recessive gene. In his phylogenetic evaluation of this group Wenger is inclined to assume orthogenetic trends, especially with regard to the steady increase in size.

Turning now to recent publications on Jurassic ammonites, I must mention first three more parts (IV-VI) of Arkell's monumental monograph on English Bathonian Ammonites that came out in 1954, 1955, and 1956 and deal with the rest of the Tulitidae, the Marcocephalitidae, the Morphoceratidae, and the first part of the Parkinsoniidae but I do not, at this juncture, venture any comprehensive evaluation of these parts.

Another recent British paper by Callomon (1955) deals with Callovian and lower Oxfordian ammonites of an English locality (Kidlington, Oxfordshire) and with the ammonite zones of the Callovian. The genera most explicitly discussed are *Kosmoceras*, *Cadoceras*, *Macrocephalites*. Most remarkable is the author's division of the superfamilies Stephanocerataceae and Perisphinctaceae of the Kellaways Clay into macroconchs and microconchs, based on his finding "that in mature shells the size is one of the most closely defined characters of a species, and often of a subgenus" and on a certain dimorphism found in *Macrocephalites* as well as in many other genera of the two above superfamilies. Thus Callomon arrives at pairing two macroconch and two microconch subgenera within the genus *Macrocephalites*, five macroconch and five microconch genera (or subgenera) within the Kosmoceratidae, three macroconch and two microconch ones within the Cadoceratidae, and two subgenera each of either group within the genus *Reineckeia*. In addition to size, the two groups are said to differ in the character of ornamentation in the adult and in the aperture which is simple in macroconchs but frequently exhibits lappets or a long rostrum in microconchs.

To another British author, M. K. Howarth, we owe a fine report on Domerian ammonites of the Yorkshire coast (1955) and an—unillustrated—list of Liassic ammonites occurring in the Scalpa sandstone of the Isle of Raasay, Inner Hebrides (1956).

Two interesting papers by Sato (1955, 1956) also deal with Jurassic ammonites, one with those of the—essentially Liassic—Kuruma group of north-central Japan, the other with a Bajocian *Stephanoceras* from the Karakuwa series of Miyagi prefecture, Japan.

All the other papers on Jurassic ammonites, some of them monographs of considerable size, that come within the scope of the present review are by German authors.

Helmut Hölder, already well known to ammonitologists for his meticulous studies on the internal shell structure (siphuncle, keel, etc.) and on "conellae" and for his discussions on the validity of Quenstedt's trinomial ammonite nomenclature, published in 1955 a comprehensive monograph on the genus *Taramelliceras* in the lower to middle "Malm" (=Callovian to lower Kimmeridgian) of southwestern Germany. It is distinguished by a great number of painstaking drawings which illustrate not only suture lines, details of the ornamentation, and whorl sections but also three-dimensional specimens, thus supplementing 4 excellent photographic plates. Although the author's approach is professedly morphological—as it should be—he allows for sufficient fluidity in his circumscription of subgenera and species. Of the former, he admits only five existing ones (*Taramelliceras* s. str., *Metahaploceras*, *Semiformoceras*, *Rollioceras*, and *Acanthoecites*), quotes three others (*Loriioloceras*, *Proscaphites*, and *Richeiceras*) between brackets only, and proposes only one new one, *Strebliticeras* (type species: *Ammonites tegulatus pictus* Quenstedt). Below the subgeneric level only four new species and six new subspecies are proposed. With regard to Callomon's distinction, reported above, between macroconchs and microconchs it is interesting to note that Hölder, too, entitles a section of his paper, published just two weeks before Callomon's, "Conch size as a specific character." However, he does not put as much emphasis on size differences as does Callomon and attributes them rather to differential speed of growth. Accordingly, he distinguished in an earlier paper (Hölder, 1952) microgerontic and macrogerontic forms rather than microconchs and macroconchs.

Zeiss' (1956) monograph on Callovian *Hecticoceras* and *Reineckeia* from a single locality in southern Germany resembles Hölder's paper in that it deals with a restricted taxonomic group in a limited area. Among 14 subgenera which the author dis-

tinguishes within the genus *Hecticoceras* are two new ones, *Zieteniceras* and *Jeanneticeras*. Only five of those subgenera are represented in the material studied by the author. Students familiar with this group will be somewhat surprised to find *Campylites*, quite generally (see also Arkell, in Treatise, p. L278) considered a subgenus of *Ochetoceras*, listed among those 14 subgenera of *Hecticoceras*. Even more baffling is Zeiss' position with regard to the type species of *Lunuloceras*. He admits that Bonarelli (as also indicated by the tautonomy) based that subgenus on *Nautilus lunula* Reinecke but from Bonarelli's quotation of "1830 *Ammonites lunula* Zieten" in the synonymy and from his own conviction that Zieten's figure does not represent the true *A. lunula* but *A. fonticola* Menke (in de Buch, 1831) he infers that the latter species has to be considered the type species of *Lunuloceras*. It may be doubted if this position is justified under the Rules. If it is, then the situation thus brought about is indeed awkward and undesirable. I (1955, p. 51) had hoped to have buried Menke's most dubious name (misspelled by Zeiss, except in his "Nachtrag," "*fonticula*," as it was by Noetling and Frebold) once and for all, only to see it now restored not only to good specific standing but even to subgenotypic rank. Thus, in this case an application with the I.C.Z.N. for restoration of *Nautilus lunula* Reinecke as the type species of *Lunuloceras* Bonarelli may well be called for. Another cause for worry to the reviewer is Zeiss' restriction of the subgenus *Brightia* to forms with a canal on the flanks. It is true that this character was postulated in Rollier's original diagnosis but later authors (Spath, 1938; Arkell, 1939; Haas, 1955) have not hesitated to include forms lacking it in *Brightia*. Zeiss' strict adherence to Rollier's definition poses the problem what to do with the latter forms, among them the most abundant species (*socini, kautzschi, syriacum*) of the Mt. Hermon fauna. Their reference to *Lunuloceras* by Bonarelli cannot be maintained. Zeiss (p. 50) himself seems to be inclined to refer them to *Rossiensiceras* Gerard and Contaut but they do not show the ogival whorl profile postulated by him for this subgenus nor its characteristic ornamentation which it seems to have in common with *Putealiceras*. Accordingly, Arkell (Treatise, p. L277) lists it as a synonym of the latter. The erection of still another subgenus of *Hecticoceras* for the forms under discussion would appear to the reviewer the least desirable solution of this problem. Zeiss follows up the treatment of four of the subgenera with diagrammatic representations of their phylogeny; this, however, appears to the reviewer too narrow an approach, neglecting the many transverse connections between those subgenera—and others not included—which are, after all, rather artificial subunits separated by fluid, more or less arbitrary boundaries (Haas, 1955, pp. 29–30). The genus *Reineckia* plays only a very minor part in Zeiss' material; it is represented by four species, all of them newly named or new, of the subgenus *Reineckeites*.

In his phylogenetic approach this author is the first of several here dealt with who operate with Schindewolf's concepts of typogenesis, typostasis, and typolysis; the others are Westermann and Bürgl (see below).

Still a third German author, Gerd Westermann, has given us in recent years valuable contributions to Jurassic ammonite lore. Two of these are systematic monographs, one (1954) on the Otoitidae, the other (1956a) on the Bajocian genera *Sphaeroceras* and *Chondroceras*.

The first of these monographs deserves to be commended for its dynamic presentation of ontogenetic changes in the Otoidae; to this presentation the reviewer has just one minor objection: In text-figure 8 the caecum should be shown *within* the median saddle of the prosuture (compare Haas, 1955, text-figs. 1, 3, 4; pl. 14, figs. 3, 4, 5, 10, 11). The author's taxonomic procedures, however, appeal much less to this reviewer. It is true that he creates only one new genus (*Germanites*) and three new subgenera (*Parallites, Platystomites*, and *Gerzenites*) of *Normannites* but he is the more generous when it comes to species or even subspecies; e.g., four subspecies, three among them new, are distinguished within the species *Otoites contractus* (Sow.), each based on from three to six individuals only. Similarly small hypodigms spread all through the monograph arouse the suspicion of splitting, and this suspicion is still deepened by the author's strictly typological approach: The description of the species or subspecies is followed by an utterly exact

description of the holo- or neotype, which, in turn, is followed by equally accurate descriptions of one or more "paratypoids." Valuable as such appreciation of minute details may be, abstraction arriving at an evaluation of a whole population would seem even more important to the reviewer. Moreover, he thoroughly misses in Westermann's work that age old requisite of description of newly established units, comparison with, and distinction from, neighboring units of the same rank, as entitled, "Remarks" in English, "Vergleichende Bemerkungen" in German, and "Rapports et Différences" in French.

The author's taxonomic approach is similar in his later monograph on *Sphaeroceras* and *Chondroceras* (1956a). Here, he claims to have succeeded in reducing the total of species arrived at in the manuscripts of his predecessors (Mascke and Rollier) to one-fifth, but his hypodigms, with few exceptions, are still pitifully small and his species descriptions appear to be open to the criticisms voiced above.

Most interesting but also—potentially—most controversial among Westermann's papers is a study (1956b) on the phylogeny of the Stephanocerataceae and Perisphinctaceae of the Dogger. Reviving ideas published by E. Pfaff as early as in 1911, this paper starts out from the fact that suture lines are only two-dimensional expressions of three-dimensional structures, the septa,* and enters into a sagacious examination of the latter, differentiating by the axes of individual lobes and saddles and creating a special terminology for the various types of septa which introduces at least a dozen of entirely new technical terms. It certainly cannot be denied, and it has been recognized ever since chambered cephalopods became a subject of scientific study, that the septal apparatus plays some important part in the mode of life although there has been much divergence of opinions as to how it actually works. However, the author's claim that all essential characters of the conch, except the ornamentation, depend on the septum seems to me to go a bit too far. It seems more likely that there prevails mutual interdependence between all these characters. The author's attempt at utilization of his septal types for the phylogenetic derivation and distinction of higher taxonomic units, up to superfamily rank, is bound to arouse criticism.

Just after the above lines had been written, Arkell's (1957b) essay on sutures and septa in Jurassic ammonite systematics reached the reviewer's desk. This essay constitutes a thorough refutation of Westermann's (1956b) septal hypothesis and of his reclassification of the Stephanocerataceae and Perisphinctaceae. For details the reader may be referred to Arkell's paper but some of its conclusions may here be quoted: "The septa and their frilled edges (sutures) are an important character in classification of Mesozoic ammonites, especially at the highest taxonomic level (suborders), but they constitute only one of a number of at least equally significant morphological characters. Below the level of the suborders no case has been made out for giving them overriding priority in phylogeny and taxonomy.

"Septa and sutures, like all other ammonite characters yet recognized—coiling, whorl shape, aperture, ribs, keels, furrows, etc.—are subject to wide individual variation, to changes during individual ontogeny, and to repetition of different variants at all levels in the phylogenetic tree and stratigraphical column. No single key to phylogeny has yet been discovered. Each character must be evaluated in relation to the whole combination in which it occurs. In one context (stratigraphical and morphological) one character may be most significant, in other contexts other characters." On the strength of his own experience, Arkell is inclined, as was Spath (1934, p. 467), at least for the Brancoceratidae, to give the style of ribbing preference over other characters. However, many ammonite groups lack costation.

New publications on Cretaceous ammonites have been recently just as prolific as those on Jurassic ones; interestingly enough, most of them deal with African (including Madagascan), Japanese, and South American faunas.

Cretaceous ammonites have, since the last years of the past century, repeatedly been recorded from Nigeria and the Cameroons but only in a recent paper by Reyment

* The author's claim that hitherto exclusively the external parts of suture lines were considered neglects the—sometimes excessive—emphasis placed by Hyatt and Salfeld on characters of the antisiphonal lobe.

(1955a) they have undergone a comprehensive treatment. In age the Nigerian faunas range from Albian to Maestrichtian. Taxonomically, they belong to 17 families some of which are split into several subfamilies each. The number of genera and subgenera is accordingly greater. Six genera (*Onitshoceras*, *Benueites*, *Kamerunoceras*, *Gombeoceras*, *Ezilloella*, and *Glebosoceras*) and two subgenera of *Pseudotissotia* (*Bauchioceras* and *Wrightoceras*) are new, though not technically so, having been proposed by the author in two preliminary papers (Reyment, 1954a, 1954b). Of particular interest to the reviewer is the close relationship of the Albian fauna with that of Angola; the interesting genera *Elobiceras* and *Neokentroceras*, best known from Angola, are well represented in Nigeria also. Study of that material leads the author to the assumption of a close relationship between *Neokentroceras* (previously linked with *Hysteroceras* by the reviewer) and *Mortoniceras*. This assumption is chiefly based on the *Mortoniceras*-like aspect of the body chamber of the holotype of *N. curvicornu crassicornutum* Reyment (pl. 4, fig. 7). It should be noted, however, especially with regard to Wright (1956), that the only slightly smaller holotype of *N. speciosum* Haas (1942b, pl. 8, fig. 14) does not show a similar change on the body chamber which occupies two-thirds of the outer whorl. (Both *N. speciosum* and *N. singulare* Haas are relegated by Reyment to synonyms of the type species *N. curvicornu* Spath.) The photographic plates of this monograph are excellent, except that now and then the author could not resist the temptation to illustrate poor specimens (e.g., pl. 16, fig. 2).

The same author followed up his monograph with a note on the phylogeny of *Gombeoceras* and *Pseudotissotia* (Reyment, 1956b).

Another brief paper of his (Reyment, 1956a) examines, along the lines followed in Hölder's earlier investigation, details of the septal suture and of the siphuncle of *Speetoniceras versicolor* (Trautschold).

As a by-product, as it were, of his Nigerian monograph Reyment published, in the same year, an essay on "Some examples of homeomorphy in Nigerian Cretaceous ammonites" (Reyment, 1955b) which may, to some extent, be considered a sequel to an earlier paper by the reviewer (Haas, 1942a). I was particularly fascinated to note that Reyment adds another example [*Discotropites sandlingensis* (von Hauer)—*Elobiceras oxytropidoceratoides* Haas], taken from my own material, to those I chose in that earlier paper. On the other hand, I note with regret that Reyment, groping for an adequate term for the phenomenon he deals with and for which he postulates heterochrony, overlooks the term "homeomorphic recurrence" proposed by Haas and Simpson (1946, p. 343) for this very phenomenon. Summarizing his observations, the author arrives at the conclusion that "the various homeomorphs . . . appear to have arisen independently of any direct connection with environmental conditions." In further considerations, some of which seem to depart quite a long way from his subject, the author (p. 585) indicates a certain belief in orthogenesis and also in Schindewolf's typostrophy; still, he concedes that "the Darwinistic view of gradually occurring change from one form to another is well illustrated by the northern Nigerian Lower Turonian collections. . . . All conceivable passage forms between the species of the various tissotiid genera have been recognized." In the last section of his paper Reyment voices some skepticism with regard to Scott's (1940) bathymetric ammonite zones, admitting, however, that some Nigerian assemblages fit well into Scott's scheme. (It may be noted here that "*galeatus*," consistently misspelled "*galleatus*" by Reyment, has been used as a specific name for ammonites, half a century before Péron, by von Hauer (1846) and, even earlier, by von Buch).

Turning to the opposite side of the African continent, we have to list three more* parts of Collignon's large monograph on Upper Cretaceous ammonites of the Menabe district of Madagascar (Collignon, 1955a and 1955b, advance prints appeared in 1952 and 1954, respectively; 1956), dealing with the Pachydiscidae, with the Kossmaticeratidae, and with the Phylloceratidae, Gaudryceratidae, and Tetragonitidae. Among the Pachydiscidae two new genera are proposed, *Hoepenites* (type species: *Pachydiscus patagonicus* Paulcke) and *Bayleites* (type species:

* The first part, on the Texanitidae, was published in 1948.

B. baylei Collignon), two more among the Kossmaticeratidae, *Karapadites* (type species: *Holcodiscus karapadensis* Kossmat, same generic name and same type species proposed a little later also by Matsumoto, see below) and *Natalites* (type species: *Madrasites natalensis* Spath), and one more, *Epiphylloceras* (type species: *Phylloceras surya* Forbes) among the Phylloceratidae. The author notes that the last family, while on the decline in most other parts of the world during the late Cretaceous, still thrives in the circumpacific areas. In his systematic treatment of the Guadryceratidae Collignon keeps *Anagaudryceras* and *Neogaudryceras* apart from *Gaudryceras*, although he questions the soundness of this generic separation in his general survey of the family. The author follows Wright and Matsumoto (1954) in rejecting certain of Shimizu's genera of Tetragonitidae. High praise is due to the excellent photographs accompanying all three of these parts of Collignon's monograph. Unfortunately he omits quite regularly the parentheses when referring to authors who quoted a given species under another generic name than the one to which it is referred in the text; this may seem a petty criticism but it cannot be denied that strict adherence to this rule facilitates the use of a paper by others.

Another prolific student of Cretaceous, predominantly Neocretaceous, ammonoidea whose work largely overlaps Collignon's is Matsumoto. So far ten of his numerous contributions, some of them published jointly with other authors, have appeared as parts of the "Studies on the Cretaceous Ammonites from Hokkaido and Saghalien" (Matsumoto 1953, Matsumoto and Hashimoto 1953, Matsumoto and Saito 1954, Matsumoto 1954a, 1954b, 1955a, Matsumoto and Obata, 1955, Matsumoto 1955b, Saito and Matsumoto 1956, Matsumoto 1956). By far the largest of these contributions (Matsumoto 1954a) deals with the Desmoceratidae and Pachydiscidae of those Japanese provinces and illustrates them lavishly in 20 plates and many diagrams inserted in the text. This paper was preceded in 1951 by a note on the Pachydiscinae, an abridged version of a paper published originally in Japanese. The two first parts of the above named series (Matsumoto 1953, Matsumoto and Hashimotu 1953) deal, however, with ammonites of other groups, the first with the ontogeny of *Metaplacenticeras subtilistriatum* (down to the protoconch, see Text-fig. 1), the second with a *Pseudaspidoceras* from Hokkaido. In the first of these papers a new subgenus of *Metaplacenticeras*, *Paraplacenticeras* (not accepted in the Treatise, p. L390) is proposed for the above named species. All the remaining parts (IV-X) of the series deal with groups belonging to the superfamily Desmoceratacae. A nearly smooth *Pachydiscus* (*Neodesmoceras*) *japonicus* is described and illustrated by Matsumoto and Saito 1954. In part V of the series Matsumoto discusses the Puzosiidae of the area, establishing a new subgenus, *Anapuzosia*, of *Puzosia* and three new genera, *Mesopuzosia*, *Neopuzosia* (relegated to subgeneric rank under *Kitchinites* by Wright, Treatise, p. L367), and *Bhimaites*, and in part VI the Kossmaticeratidae; here, too, some new generic names are proposed two among which, however, must yield to slightly older ones created by Collignon (see above): *Kaiparites* Matsumoto is a junior synonym of *Natalites* Collignon, and *Karapadites* Matsumoto a homonymous (junior) synonym of *Karapadites* Collignon. Of five other new genera three, *Marshallites*, *Hulenites*, and *Eomadrasites* were created in this paper, but two others, *Eogunnarites* and *Yokoyamaoceras*, a year earlier by Wright and Matsumoto (1954). *Marshallites olcostephanoides* Matsumoto, a species established in this paper strongly reminiscent of the Valanginian genus *Olcostephanus*, deserves special mention as a fine example of homeomorphic recurrence (see above). Somewhat less comprehensive than the two monographs just reviewed are the remaining four parts of this series. In part VII, dealing with some upper Cretaceous desmoceratids, a new subgenus of *Hauericeras*, *Gardeniceras* is proposed for *Ammonites gardeni* (not accepted in the Treatise p. L371), and in part VIII, dealing with the bituberculate pachydiscids, three new genera, *Urakawites*, *Pseudomenuites*, and *Teshioites*. Matsumoto believes in a polyphyletic derivation of *Menuites* from *Anapachydiscus* and is inclined to derive *Urakawites* from *Eupachydiscus* and *Teshioites*

from either *Nowakites* or *Canadoceras*. He notes "a small scale [isochronous] homeomorphy within the same family [Pachydiscidae]" and states the difficulty, if not impossibility, of distinguishing young *Menuites*, before the bituberculate stage, from immature *Anapachydiscus*. (For similar difficulties encountered by Collignon and Bürgl in their work see below.) Part IX, by Saito and Matsumoto, extends the stratigraphic range of *Damesites* back into the Cenomanian, and part X, constituting a supplement to part VI, discusses and illustrates some more Kossmaticeratidae, among them still another new genus, *Mikasaites;* its type species, *M. orbicularis* Matsumoto, furnishes by its close resemblance to juveniles of the Oxfordian *Taramelliceras* (*Proscaphites*) *globosum* (de Loriol) (Haas, 1955, pl. 16, especially fig. 15, to be compared with fig. 1d of Matsumoto's pl. 16) still another example of homeomorphic recurrence.

Outside this series, Matsumoto published an interesting paper (1955c) on the evolution of the Peroniceratidae.

Crossing the Pacific to the Americas, we find only one recent major paper on a North American fauna, namely Keith Young's "Upper Albian (Cretaceous) Ammonoidea from Texas." It deals exclusively with members of the subfamily Mortoniceratinae, referred to six genera, two of which, *Craginites* (type species: *Schloenbachia leonensis serratescens* Cragin) and *Drakeoceras* (type species: *D. drakei* Young) are new. Twelve out of fourteen species described are also new but the author seems to restrict his discussions mostly to the types and only exceptionally gives the measurements of from one to four other specimens. Even more rarely can the size of his hypodigms be properly assessed. Thus, the author's approach must be considered a strictly typological one. Still, he seems to fail to accept Simpson's (1940) conception of the type as a name-bearer (onamotophore) which may, but need not, be "typical," i.e. characteristic, of the taxonomic unit whose name it bears. It is this attitude of Young's that makes him (p. 17, 18) ridicule the reviewer's finding that the type species of both *Elobiceras* and *Prohysteroceras* are, in *his* words, "atypical" of their respective genera. Few paleontologists still realize that it depends on purely historical circumstances which specimen happens to become the type of a species, or which species becomes the type of a genus. Under ideal conditions, that is, if an author has a large population of individuals or a wide array of species at his disposal, he might choose from them a type that stands, so to say, exactly at the morphological center, that represents the mean with respect to all essential characteristics. A type, or a type species, so selected will indeed be "typical," i.e., characteristic, of its species or genus, respectively. This happens, however, only most rarely, if ever. As a rule, species and genera are established on single individuals determined by pure chance. Now when a later student with more abundant material on hand realizes that the specimen, or species, named first occupies a peripheral rather than a central position within its unit he faces the alternative: *either* to refer his material to the same unit, though recognizing that the original type is not quite "typical" of it, *or* to establish a new taxonomic unit for this latter reason. Thus, a not clearly understood type concept may lead to additional splitting.

In contrast to Wright (1952, p. 221, footnote 31; Treatise, p. L406) Young does not synonymize *Pervinquieria* with *Mortoniceras* but maintains it as a separate genus from which, however, he splits off his new genera *Craginites* and *Drakeoceras*, Spath's genera *Durnovarites*, *Goodhallites*, and *Cantabrigites*, *Spathiceras* Whitehouse, van Hoepen's genera *Deiradoceras*, *Arestoceras*, and *Mimeloceras*, the group of *Pervinquieria barbouri* Haas, and, of course, *Mortoniceras*, *Neokentroceras*, and *Elobiceras*. He is then left with a restricted genus *Pervinquieria* which, in his catalogue, still includes 103 species and is to him, therefore, too large and unmanageable. Now the great number of species included should not *per se* plead against the soundness of a genus. *Drosophila*, for example, includes about 600 known species but the entomologists can handle this famous genus all the same. If such a large total of species be undesirable, as it seems to be to Young, the remedy is not "breakdown into genera, subgenera," that is, further taxonomic splitting *ad infinitum*, but weeding out of synonyms, merging of species

unnecessarily kept apart, and, best of all, subdivision of the genus into species groups. Although I originally felt that by suggesting this best remedy I would run once more the risk of being considered "too conservative," I gladly realize now that on this point I am in agreement with the author who suggests, himself, this category, though in addition to genera and subgenera.

It should be mentioned that Young distinguishes, within the Mortoniceratinae, four types of juvenile costation which he terms goodhallitine, mortonicerine, pervinquieriine, and dipolocerine and which he considers useful in morphologic classification.

A minor criticism which applies to Matsumoto as well as to Young is that these authors, when transferring a species from one genus to another, hardly ever care to fit the trivial name in gender to the new generic name.

Turning now to South America, we are happy to see that the rich Cretaceous ammonite faunas of Colombia have once more been made the subject of monographic treatment. The first of several parts (1956) of a catalogue of the Ammonites of Colombia planned by Hans Bürgl deals with the Pulchelliidae, thus constituting the fourth monograph on this family, previously studied by Henri Douvillé in 1911, by Gignoux in 1920, and by Roschen in 1929, and the second that deals, as does Roschen's paper, with the Colombian Pulchelliidae in particular. Bürgl's treatment is certainly the most comprehensive this group has ever undergone. The author applies utmost care to the characterization and distinction of the various taxa. He does not add any new genus to the four previously known ones (*Nicklesia*, *Pulchellia*, *Heinzia*, and *Psilotissotia*) and admits Hyatt's genera *Gerhardtia* and *Carstenia* as subgenera of *Heinzia* only. On the other hand, Bürgl splits up Uhlig's genus *Pulchellia* into 5 subgenera (*Nicklesiella*, *Semipulchellia*, *Pulchellia* s. str., *Caicedia*, and *Hettneria*) and is rather generous in the creation of new species of which I counted 12 (plus 3 new subspecies). Taking into account that the total of individuals available was 609 (p. 7), of which, however, only 448 are enumerated in the systematic part, and that the 8 most abundant species add up to a total of 283 individuals, we are left with a balance of 165 studied specimens for the remaining 27 species and subspecies, 7 among them new, or an average of 6.1 individuals per unit. This figure seems to indicate a rather narrow circumscription of these less abundant taxa, based on an essentially typological approach. The author is, however, fully aware of the arbitrary character of some of the boundaries he felt compelled to draw. Particularly interesting are two pairs of species, mentioned in page 26, with one member of each pair exhibiting a convex venter and, therefore, referred by Bürgl to *Nicklesia*, and the other a concave one and, therefore, referred to subgenera of *Pulchellia* (*Nicklesiella* and *Semipulchellia*, respectively). (This is still another case, comparable to the one discussed by Haas (1955, p. 30), that might arouse a suspicion of sexual dimorphism.) The author emphasizes that the other morphological characters are practically the same in the two members of these pairs. Thus, the field geologist dealing with such shells, whose venters cannot be examined, would be at a loss to identify them even generically. Dr. Bürgl also notes that the concavity of the venter appears in *Nicklesiella* and *Semipulchellia* rather abruptly in the juvenile stage, at first not persisting into maturity, and quotes this phenomenon as a fine example of proterogenesis (Schindewolf). Phylogenetically, the author finds Gignoux's opinion confirmed that *Nichlesia* is the most primitive and the ancestral genus from which *Pulchellia* descended and that *Heinzia*, in turn, represents the last phylogenetic stage. This monograph is profusely illustrated, both by drawings of whorl sections and suture lines and by 21 photographic plates but some of the latter have greatly suffered in reproduction.

A second paper of smaller size by the same author (Bürgl 1956b) deals with the variability of a single species, *Dufrenoya texana* Burckhardt, from the upper Aptian of Colombia. In scope and structure it is somewhat reminiscent of an earlier paper by the reviewer (Haas, 1946).

Still another South American country, Peru, has yielded the ammonites, Valanginian to Santonian in age, carefully studied and beautifully illustrated by Benavides-

Cáceres in his "Cretaceous System of Northern Peru" (1956). We are encountering here a rich array of forms, distributed over 19 families. Of these, three are represented by four genera each, namely, the Engonoceratidae by *Engonoceras*, *Parengonoceras*, *Knemiceras*, and *Neolobites* (considered *incertae sedis* by the author), the Dipoloceratidae (= Brancoceratidae according to Wright, Treatise, p. L402) by *Oxytropidoceras*, *Venezoliceras*, *Dipoloceras*, and *Brancoceras*, and the Tissotiidae by *Barroisiceras*, *Tissotia*, *Buchiceras*, and *Heterotissotia*, one, the Vascoceratidae, by three genera: *Broggiiceras* (new), *Vascoceras*, and *Thomasites*, five by two genera each, namely, Desmoceratidae by *Desmoceras* and *Desmophyllites*, Lyelliceratidae by *Prolyelliceras* and *Lyelliceras*, Acanthoceratidae by *Sharpeiceras* and *Acanthoceras*, Mammitidae by *Mammites* and *Pseudaspidoceras*, and Coilopoceratidae by *Coilopoceras* and *Hoplitoides*, and the remaining 10 families by one genus each. As would be expected in the case of material from hitherto only little explored areas, there is a considerable number (about 25) of new species.

After having passed in review so many monographs and other papers limited in their scope to certain groups, ages, or areas, I should like to devote a few lines to "Part L, Mollusca 4, Cephalopoda, Ammonoidea" of the Treatise on Invertebrate Paleontology, published in 1957. I certainly realize that in view of the tremendous amount of knowledge condensed in this volume it is not any easier to review than, for example, a volume of the Encyclopedia Britannica. Suffice it to say that the day of its publication may well be called a feast day for ammonitologists who may now, perhaps for the first time, have recourse to an up-to-date reference work covering their whole field of study, which is not likely to become obsolete for many years and whose scope far exceeds Roman's (1938) "Essai de Genera" which covered only the Jurassic and Cretaceous ammonites. This volume is due to the cooperation of A. K. Miller, W. M. Furnish, and O. H. Schindewolf for the Paleozoic, Bernhard Kummel for the Triassic, W. J. Arkell for the Jurassic, and C. W. Wright for the Cretaceous Ammonoidea, most or all of these authors joining forces for two sections on morphological terms and on a summary of classification, respectively. In addition, Miller and Furnish contributed the general introduction, Arkell the introduction to Mesozoic Ammonoidea (pp. L81–L129) and the section on Aptychi, and R. C. Moore and P. C. Sylvester-Bradley a brief section on taxonomy and nomenclature of Aptychi. Particularly helpful to students will be the bibliography, comprising 115 titles for the Paleozoic forms, 743 for the Mesozoic ones, and 49 more on Aptychi, that is altogether more than 900 titles. As many samples taken by the reviewer prove, this bibliography has carefully been brought up to date, including, as it does, even a few papers published as late as 1956; however, it appears to be more complete for the Jurassic literature than for the Cretaceous one.

Similarly up to date are the systematic parts of the volume, as far as this was technically possible; inevitably a considerable number of new generic and subgeneric names proposed only quite recently (for example, by Drużczic, Collignon, Hölder, Matsumoto, Young, and Zeiss) missed inclusion in the Treatise. Any attempt to say more on these systematic parts, containing more than 3500 names (including synonyms) of supraspecific taxa is bound to be hopeless. However, special praise should be given to Arkell's masterly introduction to the Mesozoic ammonites which succeeds in presenting a vast field of observations accumulated through a century of research in as condensed a form as humanly possible, without omitting even the very latest (e.g., p. L92, footnote 1). As a matter of course, no unanimity among students can be expected concerning certain technical terms. Thus the reviewer would prefer to admit the term "suspensive lobe," applied by Arkell indiscriminately to the external portion of the auxiliary lobes, only where these lobes are truly "suspended," i.e., deflected ventrad (and the corresponding saddles lean more or less strongly dorsad). Arkell, however, calls such lobes "retracted." Also I believe that adventitious lobes can mostly be recognized, even without recourse to the preceding ontogeny, by the fact that they are exceeded in depth by the first lateral lobe.

A phenomenon repeatedly (especially, p.

L110) referred to by Arkell is the "plasticity" of young ammonites. To quote him, "a classification based on them generally would be very different from that based on middle and outer whorls. Large ammonites from the same horizon, otherwise identical, may possess surprisingly different nuclei. Thus, the painstaking quest after the early stages . . . would lead to the conclusion that all groups are polyphyletic, if the recapitulation theory were invariably correct." This phenomenon—as well as proterogenetic characters, such as those studied by Bürgl (p. 631)—have indeed been a perennial problem in the taxonomy and phylogeny of ammonites. Several examples of this "plasticity of the young" have been encountered in the literature here reviewed also. Thus, Collignon (1956, p. 44) treats species of the Gaudryceratidae based on inner whorls only as invalid and considers in the Pachydiscidae (1955a, p. 16) specific determination possible—or at least safe—only from diameters of from 50 to 60 mm. up, diameters, by the way, which appear quite considerable in the opinion of the reviewer who (1955, p. 30) believes that nuclei of the genus *Hecticoceras* can be specifically identified from a diameter of as little as 1 mm. Similarly, Matsumoto (1955b, p. 156) points out the difficulty of distinguishing immature *Menuites* from immature *Anapachydiscus*.

In concluding this essay review, I should like to mention that one of the most gratifying impressions gained from it is that of splendid world-wide cooperation between students in this field, for instance, between Collignon and Wright, Collignon and Matsumoto, Matsumoto and Wright, and Reyment and Wright. This high degree of cooperation is undoubtedly, to a great extent, due to the phenomenal improvement of intercontinental air travel and airmail during the last decade. Even with all this cooperation, occasional overlap and nomenclatural collisions, such as those between Collignon and Matsumoto, Hölder and Haas, Haas and Zeiss, can, of course never be entirely avoided. Particularly interesting to this reviewer among the results of such collisions are cases of synonymous homonymy, or homonymous synonymy, for that matter. After Haas (1949) had first pointed out their possibility, Frizzell (1950) declared them most unlikely to happen at the generic level but both Bairstow (1950) and Arkell (1950) produced examples that occurred at that very level. Jaworski (1955) even took pains to prove them logically impossible. Now in the literature here surveyed, I found one such case at the generic level, namely, *Karapadites* Collignon, 1954, and *Karapadites* Matsumoto, 1955, both based on *Holcodiscus karapadensis* Kossmat and, therefore, objective synonyms with the same name. Furthermore, Oecoptychiinae Westermann, 1956b, is mentioned by Arkell (1957b, p. 245) as a senior synonymous homonym of Oecoptychiinae Arkell, 1957 (Treatise); however, no such subfamily, but only a family Oecoptychiidae Arkell, nov., is found in the Treatise (p. L296). Thus, this case cannot be quoted as an example of true synonymous homonymy at the subfamily level. Even if it could, it should be kept in mind that at that level, as well as at the family level, such cases lack the thrill of those at the specific and generic levels. For an author deciding to erect a new subfamily or family is bound by the Rules to form its name by adding " . . . inae" or " . . . idae," respectively, to the stem of the name of the genus selected for type genus, so that two authors basing their higher taxa on the same genus will, of necessity, arrive at the same subfamily or family name.

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MANUSCRIPT RECEIVED SEPTEMBER 6, 1957.

JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 636–640, 1 TEXT-FIG., MAY 1958

PALEONTOLOGICAL NOTES

CORALS FROM THE UPPER ANISIAN OF HUNGARY

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During 1952 and 1953, I was able to collect corals from upper Anisian beds near the summit of Mt. Misina, Mecsek Range, southern Hungary.

Among the corals collected there are the following:

A plerophyllid-like corallite imbedded in a spongiomorphid limestone.

Coccophyllum sp. indet., a basal fragment.

Margarosmilia sp. cf. *M. confluens* (Münster) [= *M. zieteni* (Klipstein)] three corallites embedded in a gray coralligeneous limestone. This species is also found in the Ladinian beds of Hungary.

Montlivaltia sp. indet., also found in the gray coralligeneous limestone.

Thamnasteria sp. indet., found in association with *Conophyllia clepsydrae*.

Conophyllia recondita pannonica Kolosváry. Specimens of this species are rare in the gray limestone. Corallite diameter is normal for the species, 7 mm. *Conophyllia recondita recondita* (Laube) is found in Ladinian beds.

Conophyllia clepsydrae Kolosváry. Unusually large specimens of this species are found, the diameter of the corallites being 20 mm. Large colonies and fragments of colonies are abundant in the gray limestone where this species is dominant. It is characterized by reduction of the lateral sectors of the calice.

Conophyllia omphale Kolosváry. Corallite diameter in these forms is about 17 mm., the number of septa is approximately 44 as the specimens are reconstructed. Only two specimens were collected.

Spongiomorpha cf. *S. gibbosa* Frech. Found in the spongiomorphid limestone where some colonies were 2 to 3 cm. in diameter.

The coralligeneous limestone of the Misina summit area also contains many brachiopods, including *Athyris*, *Spiriferina*, *Waldheimia*, and *Terebratula vulgaris*. Associated with this is a sparse molluscan fauna of lamellibranchs and gastropods. The fauna has the character of a bank assemblage, a shallow water, littoral facies. During the upper Anisian, the transgression of the seas over southern Hungary had reached an end. The maximal stage was reached during the middle Anisian. In limestones of the middle Anisian a crinoid fauna is found together with abundant brachiopods of Recoaro affinities, molluscs, and occasional fragments of corals. This upper Anisian limestone is coralligeneous, whereas the middle Anisian limestone is crinoidal, principally containing *Encrinus* and *Dadocrinus*. In contrast, crinoids are rare in the upper Anisian beds of Misina summit.

The following table compares the Anisian, Ladinian, and upper Triassic coral faunas of Hungary.

	Upper Anisian: Mt. Mecsek	Middle and Upper Ladinian: Bakony and Bükk Mtns.	Carnian and Norian: Bakony and Buda Mtns.
Coral fauna facies	Poor bank	Rich bank	Sparse bank
Geologic activity	End of transgressive phase	Shallow waters	Shallow water, beginning of great Jurassic transgression
Distribution	Southern Hungary	Central and northern Hungary	Central Hungary

In the upper Anisian there are 9 species of corals known from Hungary, while in the Ladinian there are 35, and 12 species are known from the upper Triassic.

NOTE ON *BILEAIA* KOBAYASHI, 1954 *NOMEN NUDUM*

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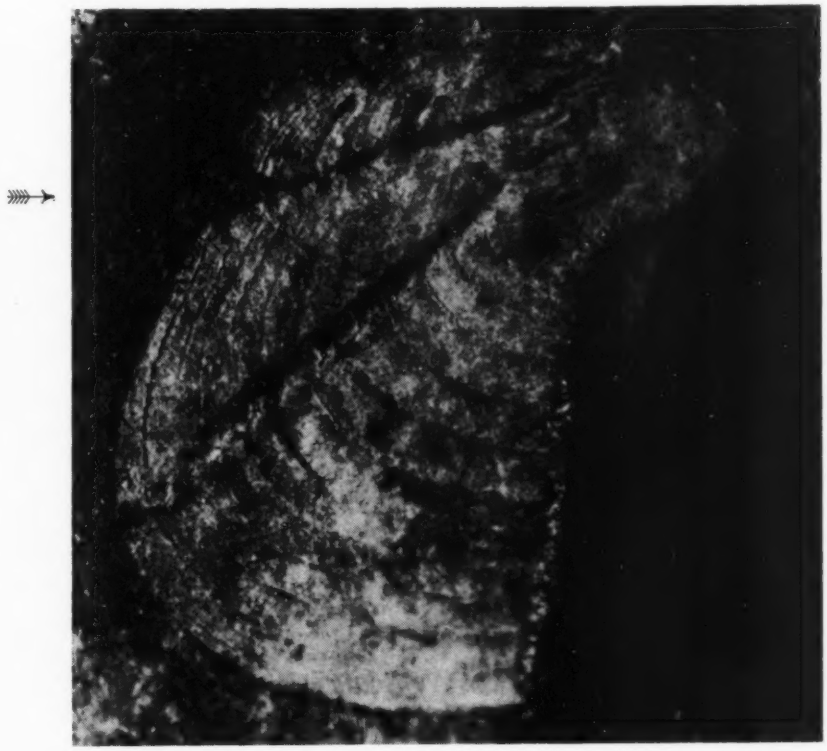
This genus, which was based on *Leaia curta* Reed (Reed, 1929, pl., fig. 18), failed to reveal the necessary details as it was figured in the original publication. For example, it was impossible to tell from the figure whether an additional, i.e., a second carina existed near the anterior margin. My notes on this genus read: "based on one incomplete specimen—questionable." Nevertheless, in the absence of contradictory data, I included it in my table of genera under the family Leaiadiidae (Tasch, 1956, Table 1). Comparison of Reed's original figure and Kobayashi's interpretive drawing (1954, fig. 30j) with the photograph of the original specimen (which was kindly provided at my request by Professor Dr. Josué Camargo Mendes of the University of São Paulo) (see Plate 1), helps to pinpoint the source of the misinterpretations.

It should be noted that the discovery that *Bileaia* was a *nomen nudum* was first made by Professor Mendes (1954, Postscriptum paragraph 5) who had an opportunity to study Reed's material. What appeared to be a possible second carina turned out to be a case of superposition. That is, the apparent second carina is a true hinge line (see Plate 1,



TEXT-FIG. *1—Leaia curta* Reed (=*Bileaia* Kobayashi, 1954, *nom. nud.*) ×25. Above the apparent second carina—the true hinge-line in actuality (see arrow)—is a portion of an overlapped second valve. In the posterior sector of this valve are nine closely spaced growth lines. The growth lines in the dorsal posterior sector of the larger overlapping valve are five in number and they do not correspond to those on the opposite side of the hinge-line. (Photograph of Reed's type provided by Professor Dr. Mendes.)

arrow) and it slightly overlaps a portion of another specimen. That such overlap is a reality can be readily determined from the photograph provided by Professor Mendes. In the lowermost part of the posterior sector of the partial valve beyond the hingeline, one can count nine growth lines while in the larger overlapping specimen in the same distance and region, one can count only five growth lines. This bears out Professor Mendes' observation (personal communication, May 21, 1957) that "the concentric lines above the true hingeline are finer and discordant." In other words, they are not a continuation of growth lines below the true hingeline.

Novojilov (photocopy of correspondence with Professor R. C. Moore, June 12, 1957) lists *Bileaia* Kobayashi 1954 under a family Cycloleaiidae Nov. 1952. In other words, all workers who have not seen the type material, as has Professor Mendes, were equally misled in accepting *Bileaia* as a valid new genus. Since Professor Mendes (1954, *op. cit.*) has published no actual evidence to sustain his decision that *Bileaia* was a *nomen nudum*, the present note, made possible with his cooperation, makes public the evidence.

The present example may also serve as a caution to taxonomists. The erection of new genera based on (a) incomplete material (e.g., Reed's specimen is a broken fragment), (b) single specimens, and (c) inadequately described and figured published material, is a highly speculative procedure. In such instances, the assignment should be held in abeyance or put in question. At any rate, inability to make a clearcut decision should not find expression in a new scientific name which is worthless in the present case.

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NEBRASKA'S LOESS DEPOSITS—GRASSLAND OR WOODLAND ENVIRONMENT?

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Many attempts have been made to determine the types of vegetal cover which existed during Pleistocene loess deposition. The realization of this goal has been slow because in general loess is not a satisfactory environment for the preservation of plant materials. To account for the general absence of preserved plant material in loess Shimek (1896, p. 86) stated:

> No plant remains of undoubted loess origin occur. As the plants undoubtedly existed during the entire period, the deposition must have gone on so slowly that ample time was given the plant remains to crumble in decay and mingle with the soil.

Since Shimek's hypothesis was presented, there have been very few discoveries of well preserved plant material. The most notable of these are Voss' (1933) report of moss and larch in the upper loess at Peoria, Illinois, and Kay & Graham's (1943) report of yew, spruce, and hemlock in the lower part of the Peorian loess of Iowa.

Because plant remains are rare many researchers have indirectly determined the flora by utilizing the ecological requirements of the mollusks found in loess. On this basis Shimek (1930) and Baker (1931) both suggested that woodlands, forests, thickets and grasslands existed in the areas in which loess was accumulating. Kay & Graham (1943) were more specific; utilizing Cameron's (1940) mollusk data they suggested that a constant forest-prairie relationship existed over Iowa from Peorian until the present time. Leonard (1952) presented a different picture for Kansas. He concluded that the regions of post-Yarmouth and pre-Brady

loess accumulation were covered by grass, herbs and shrubs.

In Nebraska an evaluation of the flora from both mollusks and carbonaceous material seems possible. Mollusks found in the loess deposits indicate that the areas of deposition were covered by grass, herbs, and shrubs. This is in agreement with Leonard's (1952) findings in Kansas. Because typical forest dwelling forms are absent, Shimek's (1896) hypothesis that loess was deposited primarily in forests can not be applied to Nebraska.

Carbonaceous material found in loess provides additional information concerning the flora. Field study indicates that loess contains more or less abundant carbonaceous material. When samples of loess are disaggregated by a gentle stream of water, much more carbon can be observed than is seen in dry specimens. Most of the carbon consists of small flakes disseminated throughout the loess. However, in many instances, blade-like fragments, one to five inches in length are found. Cylindrical fragments of carbonized material, one-fourth to one inch in length are also common. This carbonized material is thought to be direct evidence of the existence of plants in the areas of and at the time of loess deposition. The elongated carbon blades and cylindrical fragments probably attest to the existence of grass and shrubs.

No evidence for the existence of trees was found in the loess deposits examined, but many of the alluvial deposits of Nebraska contain seeds and pieces of carbonized wood which are large enough to suggest that they might have come from trees. The writer has found these seeds only in alluvial deposits, and as far as he can ascertain all other finds in Nebraska are restricted to alluvial or colluvial materials.

From the evidence based upon the ecology of the mollusks and the distribution and type of plant remains found in the sediments, it is concluded that during the late Pleistocene trees were generally restricted to narrow areas along the stream valleys (forming "gallery forests"), and the flora of the loess plains of Nebraska consisted mainly of grasses and shrubs with only occasional small trees.

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MANUSCRIPT RECEIVED OCTOBER 11, 1957.

A NEW PLEISTOCENE MOLLUSCAN FAUNA FROM CONNECTICUT

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In 1930 G. Arthur Cooper described the fauna of a Pleistocene marl in New Milford, Connecticut. He identified the following mollusks from this deposit.

Sphaerium rhomboideum	common
Musculium partumeium	rare
Pisidium abditum	very common
P. contortum	rare
P. ferrugineum	rarely common
P. rotundatum	rare
P. ventricosum	rarely common
Valvata tricarinata	rare
Physa cf. *ancillaria*	very rare
P. cf. *heterostropha*	very rare
Ferrissia rivularis	very rare
Helisoma anceps striatum	very rare
H. campanulatum	very common
Gyraulus altissimus	abundant
G. deflectus	rare
Lymnaea stagnalis jugularis	common
Fossaria galbana	very common
F. obrussa decampi	rare
Vertigo ovata	very rare

The fauna described by Cooper was the only one known until 1956, when H. E. Simpson of the U. S. Geological Survey discovered mollusks in sediment dredged from a small stream channel in New Britain, Connecticut. He informed the writers of this find, and, in 1957, sediment containing mollusks was collected.

The collecting site is located in the stream valley approximately 100 feet north of the intersection of the stream with Allen Street. The stream is approximately three-eighths of a mile east of the Allen Street cemetery. The fossiliferous sediment is a grey to greyish brown carbonaceous silt approximately 18 inches thick. Seeds, plant stems and leaf fragments are abundant in the sediment. This material is not visible; its top is approximately 9 inches below the stream level. The lower part of the stream channel is apparently cut into this material. The areal extent of the fossiliferous zone along the stream channel appears to be limited. Augering and examination of the dredged material indicated that its length is restricted to a few feet.

The following mollusks were collected from this site:

Pisidium spp.—abundant; a few species present
Valvata lewisi—common; some individuals closely resemble *V. sincera*, and many belong to this species
Ferrissia parallela—rare; only one specimen found
Helisoma spp.—rare; only immature individuals found; cf. *H. anceps* and *H. campanulatum*
Gyraulus altissimus—abundant
Lymnaea sp.—rare; only immature individuals found; cf. *L. stagnalis juglaris*
Fossaria galbana—abundant
F. obrussa decampi—rare
Cincinnatia cincinnatiensis—rare

Although the New Britain locality appears to have a more restricted fauna than does the New Milford deposit certain similarities and dissimilarities are apparent. In both areas *Pisidium* spp., *Gyraulus altissimus* and *Fossaria galbana* are prominent. Specimens of *Physa*, which are rare in New Milford, appear to be absent in New Britain. A number of forms not reported from the New Milford deposit are present in New Britain. These include *Cincinnatia cincinnatiensis*, *Ferrissia parallela* and *Valvata lewisi*. In New Milford *Ferrissia* and *Valvata* are present but are represented by different species.

The age of the New Britain deposit is not known. It may be the same age as the New Milford deposit which Cooper (1930) assigns to the post-Wisconsin Wabash interval, but because no forms with restricted range occur no definite age assignment can be made.

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JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 641, MAY 1958

NOMENCLATURAL NOTE

FENESTELLA OVATIPORELLA, NEW NAME FOR *F. OVATIPORA* ELIAS

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University of Nebraska, Lincoln

FENESTELLA OVATIPORELLA Elias, n. name

1957. *Fenestella ovatipora* Elias, Jour. Paleontology, v. 31, no. 2, p. 407, pl. 44, fig. 7 (not Rogers, 1900, Kansas Univ. Quart., ser. A, v. 9, no. 1, p. 6, pl. 2, fig. 1).

My attention was called to the fact that the specific name *ovatipora* is preoccupied by A. F. Rogers for *Fenestella ovatipora* from the Kansas City group, Pennsylvanian, of Kansas City, Missouri. Hence a new name must be given to my species *F. ovatipora* from the Redoak Hollow.

The meshwork formula is 18–19/10–10.5//18–19/5–8, while that of *F. ovatipora* Rogers is 14/8//17, as per Rogers' measurements (1900, p. 6, pl. 2, fig. 1).

JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 642–644, MAY 1958

NOTICES

COLLOQUIUM ON ZOOLOGICAL NOMENCLATURE TO BE HELD IN LONDON IN JULY, 1958 IN CONNECTION WITH THE FIFTEENTH INTERNATIONAL CONGRESS OF ZOOLOGY

It is hoped that at the Fifteenth International Congress of Zoology to be held in London in July, 1958 it will be possible for that Congress finally to approve and adopt the new text of the International Code for Zoological Nomenclature as revised by the proceding Congresses held in Paris in 1948 and Copenhagen in 1953. As arranged at the Copenhagen Congress, a draft of the revised text will be submitted for this purpose to the London Congress.

In order to assist the Congress in the examination of the draft of the revised Code and to provide ample opportunity for the discussion of the questions involved, arrangements have been made between the Secretariat-General of the Congress and the International Trust for Zoological Nomenclature under which a Colloquium on Zoological Nomenclature is being organized by the International Trust on the lines of the Colloquium organized by that body in connection with the Copenhagen Congress.

The Colloquium will open on Wednesday, the 9th July i.e. one week prior to the opening of the London Congress. It is hoped that this body will be able to relieve the Congress of the bulk of the work involved in the scrutiny of the draft of the revised Code and will be able to submit to the Congress agreed recommendations as to the text to be adopted. Invitations to the Colloquium have already been issued by the Trust to a large number of zoologists known to be interested in zoological nomenclature. In addition, arrangments have been made between the Trust and the Secretariat-General of the Congress under which an invitation to the Colloquium will be issued by the Trust to any member of the Congress who expresses a desire to take part in its discussions but who has not as yet received a separate invitation.

FOSSILS IN THE PUBLIC DOMAIN

Rules and regulations prescribed by the Secretaries of the Interior, Agriculture and the Army governing the collecting of fossils in the public domain, with reference to [the appropriate law or laws to be supplied]:

1. Jurisdiction over fossils in the public domain shall be exercised by the Secretaries of the Interior, Agriculture and the Army in all lands under their respective jurisdictions.

2. General permits for the collecting of fossils in the unassigned lands under his jurisdiction will be granted to reputable museums, universities, colleges or other recognized organizations by the Secretary of the Interior.

3. Applications for such permits shall be referred to the Smithsonian Institution for recommendation.

4. Such permits shall be valid for a period of ten years from the date of issue, and may thereafter be renewed for further ten year periods.

5. Such permits may be revoked at any time upon evidence of misuse.

6. The responsible officer or officers of organizations holding such permits shall have the right of designating persons to carry out collecting operations, and shall provide such persons with proper credentials

7. Possessors of general permits for collecting fossils on unassigned lands, and only such possessors, may apply to the Secretary having jurisdiction for permission to collect fossils in designated areas (National Parks, National Monuments, National Forests and Military Reservations). Each such application shall specify the nature of the proposed work, the area or areas involved, and the length of time proposed to be devoted to it.

8. Government field officers in charge may at all times examine the credentials of any field party claiming privileges granted in accordance with these rules and regula-

tions, and may fully examine all work done under permit.

Washington, D.C. (Date)

The foregoing rules and regulations are hereby approved in triplicate and, under authority conferred by law on the Secretaries of the Interior, Agriculture and the Army, are hereby made and established to take effect immediately.

Secretary of the Interior
Secretary of Agriculture
Secretary of the Army

INTERNATIONAL PALEONTOLOGICAL UNION

The International Paleontological Union has hitherto functioned as a department of the International Geological Congresses, but at the 1956 Congress in Mexico it was decided to extend its activities, and it is now proposed to publish a Directory to the Paleontologists of the World. The expanding interests of the Union have necessitated arranging a meeting previous to the next Geological Congress, planned for 1960 in Copenhagen, and the President of the Union (Dr. Maldonado-Koerdell, Mexico City) had decided to call a meeting to coincide with the XVth International Congress of Zoology, and the preceding Colloquium on Zoological Nomenclature, to be held in London during the period July 9th to 23rd. During this session the Union will discuss and adopt a revised Constitution, as modified from that first put forward in 1956 at Mexico. All interested paleontologists are asked to write to the Secretary for further particulars: Dr. Jean Roger, Service d'Information géologique, B.R.G.G.M., 74 rue de la Fédération, Paris XVe.

PROPOSED USE OF THE PLENARY POWERS

Notice is hereby given that the possible use by the International Commission on Zoological Nomenclature of its Plenary Powers is involved in applications relating to the under-mentioned names included in Double Part 10/11 of Volume 13 and Part 1 of Volume 16 of the *Bulletin of Zoological Nomenclature* which was published on 30th December, 1957.

Monograptus fimbriatus var. *similis* Elles (G. L.) & Wood (E. M. R.), 1913; *Monograptus triangulatus* var. major Elles & Wood, 1913; *Monograptus communis* var. *rostratus* Elles & Wood, 1913: designation of lectotypes for (Class Graptolithina) (Z.N.(S.)1248);

The present Notice is given in pursuance of the decisions taken on the recommendation of the International Commission on Zoological Nomenclature, by the Thirteenth International Congress of Zoology, Paris, July 1948 (see *Bull. zool. Nomencl.* 4:51–56, 57–59; *ibid.*5:5–13, 131).

Any specialist who may desire to comment on any of the foregoing applications is invited to do so in writing to the Secretary to the International Commission (Address: 28 Park Village East, Regent's Park, London N.W.1. England) as soon as possible. Every such comment should be clearly marked with the Commission's File Number as given in the present Notice, and sent *in duplicate.*

In consequence any comments on the applications published in these Parts should reach the Secretariat of the International Commission at the latest by 30th June 1958.

FRANCIS HEMMING
Secretary to the International Commission on Zoological Nomenclature

PACIFIC COAST SECTION

The following officers were elected at the March 28 meeting of the Pacific Coast Section of the Paleontological Society:

Chairman:	V. S. Mallory
Vice Chairman	J. F. Lance
Secretary	R. L. Langenheim, Jr.
Councilor	H. E. Wheeler

PALEONTOLOGICAL SOCIETY

JUBILEE CELEBRATION AT THE ANNUAL MEETING, NOVEMBER, 1958

The Paleontological Society will celebrate its Fiftieth Anniversary at the Annual meeting in St. Louis, 6–8 November 1958. A special Jubilee Committee was established by the Council to plan an appropriate recognition of this anniversary.

A program for one special session of the meeting is being planed with talks by invited speakers on each of the branches of paleontology—Paleobotany, Invertebrate Paleontology, Vertebrate Paleontology, Micropaleontology and Paleoecology. These talks will review significant discoveries of the past 50 years, the techniques that made these achievements possible, and likely future advances.

On this occasion of paleontologic emphasis it seems to the Jubilee Committee that an especially strong program of paleontological papers is to be desired for the regular session. Members of the Society are urged to submit paleontological papers for the program, noting the deadline for abstracts of July 1 set by the Joint Program Committee of the Geological Society of America. (Abstracts should be submitted on forms obtained from The Secretary, Geological Society of America, 419 West 117th Street, New York 27, New York.)

It may prove feasible to incorporate some or all of the technical papers to be presented on this occasion in a special "Festschrift" volume.

The Jubilee Committee has under consideration two further items: (i) the holding of a special Paleontological Society luncheon or dinner at St. Louis; (ii) the establishment of a Paleontological Society Merit Award. The Chairman of the Committee, Dr. G. Arthur Cooper, U. S. National Museum, Washington 25, D.C., will welcome the opinion of members as to the desirability of the first and suggestions for the second.

JOURNAL OF PALEONTOLOGY, V. 32, NO. 3, P. 645–646, MAY 1958

SOCIETY RECORDS AND ACTIVITIES

In accordance with Article 3, Chapter 1 of the By-Laws of the Paleontological Society, the Secretary submits the following nominations for membership in the Society. The list has been approved by the Council of the Society.

BALME, BASIL ERIC, Department of Geology, University of West Australia, Nedlands, W. A.: B. F. Glenister, W. M. Furnish.

CARTER, JOHN LYMAN, 210 N. 9th St., Grand Forks, No. Dakota: F. D. Holland, Jr., John R. Bergstrom, Jon L. Rau.

COLOMBINI, VICTOR, Department of Petroleum and Geological Engineering, Louisiana Polytechnic Institute, Ruston, La.: Wm. R. Higgs, C. W. Wolf, John Oleksyshyn.

COUSMINER, HAROLD LEOPOLD, 306 West 78 Street, New York 24, N. Y.: Angelina R. Messina, Noel K. Brown, Jr., Raymond L. Artusy.

ALENCASTER DE CSERNA, MRS. GLORIA, Institute de Geologia, Ciudad Universitaria, Mexico 20, D. F. Mexico: Norman D. Newell, John Imbrie.

DAVIES, MRS. HANNELORE MARTEN, 12-E Vetville, Oxford, Ohio: W. H. Shideler, Karl E. Limper, Kenneth E Caster.

DAVIES, RHYS JENKI , 12-E Vetville, Oxford, Ohio: W. H. Shideler, Karl E. Limper, Kenneth E. Caster.

DUBAR, JULES RAMON, Department of Geology, University of Houston, Houston, Texas: Raymond C. Moore, J. M. Jewett.

FRITZ, WILLIAM HAROLD, Cathlamet, Washington: V. Standish Mallory, Harry E. Wheeler, Betty Joyce Embysk.

GALLITELLI, EUGENIA MONTANARO, Instituto di Geologia e Paleontologia, Universita, Modena, Italy: John B. Reeside, Jr., G. Arthur Cooper, Helen Duncan.

GERMEROTH, ROBERT M., 49 Delvin Terrace, Wilmington 5, Delaware: Horace G. Richards, B. F. Howell.

GUARRAIA, ERNEST, C. V., c/o Overseas Services (Philippines) Inc., Box 1713, Intramuras, Manila, The Philippines: Angelina R. Messina, Brooks F. Ellis, Robert E. King.

HORNÝ, RADVAN, Karlštejn 1/129, Prague, Czechoslovakia: Ellis L. Yochelson, John B. Reeside, Jr., G. Arthur Cooper.

JOHNSTON, IAN MCKAY, 1446 Berkeley Way, Berkeley 2, California: R. L. Langenheim, Jr., Joseph H. Peck, Jr., J. Wyatt Durham.

JONES, DANIEL HUBBARD, Humble Research Center, 3120 Buffalo Speedway, Houston, Texas: Stuart A. Levinson, Russell M. Jeffords, Robert G. Todd.

KAAR, ROBERT FREDERICK, Department of Paleontology, University of California, Berkeley 4, Calif.: R. L. Langenheim, Jr., J. Wyatt Durham, Joseph H. Peck, Jr.

LEE, ROBERT EDWARD, 1215 Weber Drive, Lansing, Michigan: C. E. Prouty, Jane E. Smith, Erwin C. Stumm.

LEROY, DUANE OSMOND, P. O. Box 2180, Humble Oil and Refining Company, P. O. Box 2180, Geol. Res. S-264, Houston, Texas: Russell M. Jeffords, Harold N. Fisk.

LOGAN, BRIAN WARREN, Geology Department, University of Western Australia, Nedlands, W. Australia: Brian F. Glenister, W. M. Furnish.

MCALESTER, A. LEE, 243 Park Road, Hamden 17, Conn.: Carl O. Dunbar, Karl M. Waagé.

MCTAVISH, ROBERT ALEXANDER, 62 Robert Street, Como, Western Australia: Brian F. Glenister, Wm. M. Furnish, Jr.

MALAVASSI, VARGAS ENRIQUE, San José, Costa Rica, P. O. Box 2549: W. P. Woodring, Axel A. Olsson.

MEADE, ROBERT FRANCIS, 1274 Armacost, Los Angeles, California: Peter U. Rodda, C. A. Nelson, Lou E. Rankin Saul.

ROBISON, RICHARD ASHBY, 640 North 7th East, Provo, Utah: J. Keith Rigby, Harold J. Bissell.

SABOL, JOSEPH WILLIAM, Box 5524, Virginia Tech. Station, Blackburg, Va.: Chauncey G. Tillman, Byron N. Cooper.

SULZE, LAURENCE RICHARD, 7859 Litzsinger Rd., Brentwood 17, Mo.: Kenneth G. Brill, Jr., H. B. Whittington.

VAUGHN, PETER PAUL, U. S. National Museum, Washington 25, D. C.: C. L. Gazin, John B. Reeside, Jr., G. Arthur Cooper.

VONDRA, CARL FRANK, 3821 Steele Ave., Lincoln, Nebraska: Walter Sadlick, T. M. Stout.

WADDELL, DWIGHT ERNEST, Department of Geology, University of Oklahoma, Norman, Okla.: Carl C. Branson, George G. Huffman, E. A. Frederickson.

WIGGINS, VIRGIL DALE, P. O. Box 45 WWC, Norman, Oklahoma: Carl C. Branson, Thomas W. Amsden, E. A. Frederickson.

WOLFE, JACK ALBERT, Department of Paleontology, University of California, Berkeley, California: Wayne L. Fry, J. Wyatt Durham, R. A. Stirton.

WOODLAND, ROLAND BERT, c/o Shell Oil Co., Box 1136, Grand Junction, Colo: Harold J. Bissell, J. Keith Rigby.

NOTICE TO ALL MEMBERS REGARDING ELECTION OF NEW MEMBERS TO THE PALEONTOLOGICAL SOCIETY

Article IV, section 1 of our Constitution (Geol. Soc. America, Proceedings Volume for 1948, p. 267–272, 1949) reads:

1. Election to Membership. Each candidate for Membership shall submit to the Council an application on a form authorized by the Council for this purpose, signed by him, and endorsed by not less than two Members who are in good standing and who are acquainted with his qualifications. Action upon the application shall be made by the Council in the manner prescribed in the By-laws.

Chapter 1 of the By-Laws prescribes the manner of election as follows:

1. Nominations for Membership may be proposed at any time on blanks to be supplied by the Secretary of the Society.

2. The form for nomination shall be as follows:

In accordance with his (or her) desire, we respectfully nominate for Member of The Paleontological Society: Full name; degrees, if any; address; occupation; branch of Paleontology now engaged in.

(Signed by at least two Members, as provided in Article IV, Section 1, of the Constitution.)

3. At each regular meeting of the Council, or at any meeting specially called for this purpose, or by mail, the nominations received by the Secretary shall be examined and, if approved, shall be forwarded to the Editor for early publication in the Journal of Paleontology.

If, within sixty days following publication, no challenge to the applicant's eligibility has been received by the Secretary, it shall be deemed that the applicant is elected a Member, and he shall be so notified by the Secretary.

But if, within this time cause is indicated by any Member why the applicant should be rejected, the final declaration shall be withheld by the Secretary and the facts communicated to other members of the Council who, after due investigation, shall vote (either by mail or in person) whether to accept or reject the application. If the Council votes to accept the candidate in spite of such criticism, this shall constitute election, and the candidate shall be notified by the Secretary that he is a Member; but if the Council shall not so decide then it shall be deemed that the applicant has failed of election.

The requirements of publication of the nominations and of waiting 60 days for a "challenge to the applicant's eligibility" means that the shortest time that may elapse between nomination and becoming a member is 5 months, and the delay may be 1 year. The Council feels strongly that this is a quite unnecessary delay and recommends that the method of election of members be changed. Such a change necessitates amendment of the By-Laws, which may be effected by a majority vote of the membership. Accordingly, Council proposes that the present section 3, Chapter 1, of the By-Laws be deleted, and a new section inserted, to read:

3. At each regular meeting of the Council, or at any meeting specifically called for this purpose, or by mail, the nominations received by the Secretary shall be examined. Approval of a nomination by a majority of the Council shall constitute election of a member, and he shall be so notified by the Secretary. The names of new members shall be forwarded to the Editor for early publication in the Journal of Paleontology.

This proposal will be the subject of a ballot of the membership, taken at the same time as the annual ballot for officers, in September, 1958. If the membership votes to accept this recommendation, it will mean that the interval between receipt of a nomination by the Secretary and action by the Council will be reduced to a few weeks.

H. B. WHITTINGTON
Secretary

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REVIEWS

TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY. Volume 1. Ecology. Joel W. Hedgpeth, Editor. Geological Society of America, Memoir 67. viii and 1296 pages, illustrated. 1957. $12.50.

This remarkable volume is a valuable summary of nearly all aspects of marine ecology. Though its subject materials were obviously chosen to be of maximal value in presenting recent marine ecology to geologists, about the only omissions the ecologist will notice are the lack of articles on primary productivity and population dynamics.

While division into sections is not actually made, the twenty-nine chapters fall (probably not by chance) into readily recognizable sections on General Ecology (chapters 1–4), Physical and Chemical Characteristics of the Marine Environment (chapters 5–14), Interrelationships of Organisms (chapters 15 A-C), Marine Communities (chapters 16–23), The European Inland Seas (chapters 24–26), and Introduction to Population Behavior (chapters 27–29).

The first of these sections covers marine environments, concepts of marine ecology, and means of obtaining ecological data in the sea. The second discusses the general features of the oceans, light, salinity, temperature, oxygen, carbon dioxide and carbonates, plant nutrient elements, trace metals, biogeography, and organic detritus. Commensalism, parasitism, and symbiosis are described in the third section. Chapters 16 through 23 deal with habitat features and community types of the plankton, benthos, rocky intertidal zone, sandy beaches, coral reefs, submarine canyons, bathypelagic and abyssal regions, and estuaries and lagoons. The European Inland Seas (Baltic, Black, Azov, Caspian, and Aral) which have features of specific interest or unusual nature are described in Chapters 24–26. This reviewer believes that papers on the Mediterranean, Adriatic, and Dead Seas would also have been useful.

The only section which falls seriously short of realizing its potential is the last. Chapter 27 on lunar periodicity deals with short-period cycles which are interesting in themselves but have very little likelihood of ever being recognized in, or successfully interpreted into, paleoecology. Chapter 28 on fluctuations in littoral populations is trivial. Analyses of recent mass mortalities among marine organisms are given in Chapter 29 where 105 mass mortalities are described. This is the worth-while chapter of the section. Papers describing at least the typical growth curves of populations and the year-class-analysis method now routine in fishery biology would have brought this section nearer to the degree of usefulness achieved in the other sections.

The volume closes with 213 pages of annotated bibliography containing more than 2100 references. The bibliography is arranged under headings for books, general papers, estuaries, fouling, borers, bacteria, algae, non-algal plants, diatoms, protozoa, sponges, corals, bryozoa, brachiopods, worms, oysters, *Nautilus*, other mollusca, crustacea, ostracoda, copepoda, Xiphosura, miscellaneous arthropods, insects, crinoids, starfish, echinoids, holothurians, cyclostomes, fishes, amphibians, reptiles, sea turtles, birds, and mammals. Extensive bibliographies are given with nine of the chapters. In several of the articles there are references to more specialized bibliographies published elsewhere.

In addition to covering nearly all of marine ecology and providing outstanding bibliographic resources, this volume updates several parts of the standard text on oceanography. It will be of use to oceanographers, and is virtually a "must" for marine ecologists.

The editor and contributors are to be congratulated for a piece of work well done. Dr. Vaughn and the many who collaborated in various ways have in this Memoir a monument to their foresight and tenacity of purpose.

JOHN C. AYERS
Assoc. Prof. of Zoology,
University of Michigan
Associate in Biology,
Woods Hole Oceanographic Institution

PALAEONTOLOGY, v. 1, no. 1, November, 1957, 86 p., 14 collotype plates. Published by the Palaeontological Association. Ed. Dr. W. H. C. Ramsbottom, Geological Survey and Museum, Exhibition Rd., London, S.W.7, England. (Annual subscription price to members—individual, institutional—$6.25, payable to the Treasurer, Dr. W. S. McKerrow, University Museum, Oxford University.)

New journals in paleontology are as rare as they are welcome. This new effort by the recently organized (1957) Palaeontological Association is especially attractive. Like the *Journal of Paleontology*, its objective is the publication of preferably illustrated articles on all aspects of paleontology and, to quote from their front cover prospectus, "stratigraphical paleontology." Two numbers a year are planned. Since these are individually priced at $5.20 each, it is clear that membership in the Association is a bargain.

The initial number treats entirely with invertebrates: D. V. Ager on the true Rhynchonellids; W. S. Bisat on Upper Viseén goniatites; A. Wood on the type species of the alga *Girvanella;* R. Casey on the Cretaceous ammonite genus *Leymeriella;* R. P. Tripp on the trilobite *Encrinurus multisegmentatus;* G. F. Elliott on a new Tertiary calcareous alga *Subterraniphyllum;* and D. J. Carter on the distribution of the foraminifer *Alliatina excentricus* and the new genus *Alliatinella.*

The British colleagues have produced a very attractive journal, far more costly in all respects than the American counterpart. This is reflected by the superior paper stock, single, whole-page type line, and larger type in *Palaeontology.* The result is a far more pleasing journal. Certainly in the United States it would be impossible to produce this quality of documentation without a very substantial subsidy beyond membership fees. The British tradition of excellent photographs and fine collotype plates is continued. It is good to note that in at least one of the papers here printed the ammonium chloride process of whitening specimens before photography has been employed. The results should encourage more of our over-seas colleagues to do likewise.

KENNETH E. CASTER
University of Cincinnati

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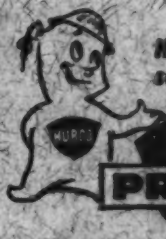

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